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A COMPREHENSIVE WATER POLLUTION CONTROL PROGRAM FOR THE LAKE MICHIGAN BASIN, GREEN BAY AREA, MICHIGAN AND WISCONSIN

Federal Water Pollution Control Administration
Chicago, Illinois

June 1966

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COMPREHENSIVE WATER POLLUTION CONTROL PROGRAM
FOR THE
LAKE MICHIGAN BASIN

Green Bay Area, Michigan and Wisconsin

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Springfield VA 22151

June 1966

U. S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Great Lakes-Illinois River Basins Project
Region V

Chicago, Illinois

GPO 826-535-1

12-81

FOREWORD

The Department of the Interior welcomes the opportunity afforded by the Honorable Warren P. Knowles, Governor of the great State of Wisconsin, to present this portion of our comprehensive water pollution control program for the Lake Michigan Basin at Green Bay, Wisconsin on June 30, 1966.

The action program set forth in this document, when implemented, will protect and enhance the quality of the waters of the Green Bay Area. It will increase their usefulness for recreational purposes. It will provide a more suitable environment for fish and aquatic life and add to the value of this resource. It will improve the quality and usefulness of the area's waters for municipal and industrial purposes, esthetic enjoyment and many other beneficial uses.

Working together as a team, the agencies concerned with the control of water pollution at all levels of government can, and will bring this program to fruition for the benefit of the people of Michigan, Wisconsin and the Nation.

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SUMMARY

General

The waters of the Green Bay Area, Michigan and Wisconsin, particularly the Lower Fox River and the southern end of the Bay itself are seriously degraded in quality. Other significant areas of water quality impairment include the mouths of the Escanaba, Menominee, Peshtigo and Oconto Rivers and certain upstream reaches of these Green Bay tributaries. Biological, chemical, microbiological and physical parameters analyzed by the Great Lakes-Illinois River Basins Project indicate this fact.

Pollution of the waters of the Green Bay Area is further evidenced by the destruction or impairment of legitimate water uses. The City of Green Bay obtains water from Lake Michigan for municipal use rather than using the adjacent waters of Green Bay. Public bathing beaches in this area were closed more than 25 years ago. The fishery in extreme southern Green Bay is virtually non-existent. Esthetic enjoyment is impaired by the unsightly appearance of the waters of the Lower Fox River. In other locations of the Green Bay Area high coliform counts and low dissolved oxygen levels impair recreation and fish and wildlife support. The growth of undesirable amounts and kinds of algae in certain areas further impairs use of the waters for municipal supply and recreational activities.

Sources of Pollution

The most significant sources of pollution in the Green Bay Area are the pulp and paper mills discharging their wastes to tributaries or to the Bay itself. These wastes have an estimated population equivalent (PE) of 2,600,000. To put this another way, the industrial wastes discharged to the waters of the Green Bay Area are equivalent in terms of oxygen consuming power to the raw wastes of over 2,600,000 persons.

Municipal waste treatment plants of the Green Bay Area serve a present population (1960) of 454,000. These plants receive an estimated additional industrial waste load of 300,000 PE, the combined effluents from these municipal waste treatment facilities discharge a total of 51,000 pounds of 5 day biochemical oxygen demand (BOD_5) daily to the waters of the area. Municipal waste treatment plant effluents are the second largest source of pollution in the Green Bay Area.

In addition to the oxygen consuming wastes other significant waste constituents include phosphates, phenols, ammonia nitrogen and fecal bacteria.

Future Conditions

Growth projections made by the Great Lakes-Illinois River Basins Project economists indicate that the 1960 Green Bay Study Area population of 710,000 may increase more than two-fold by 2020. Industrial activity, due primarily to productivity and increased demands, is expected to double by approximately 1980 and continue to expand in the decades that follow. Water demands and waste flows will increase at a more moderate pace due to water reuse and other efficiencies. These and other related factors indicate that the untreated waste load received by all municipal sewerage systems in the study area will increase to about 2,220,000 PE by 2020. By comparison, the present estimated untreated waste load received by all municipal plants of the Green Bay Area is approximately 750,000 PE.

Need for Comprehensive Program

The present severe impairment of water uses in the area and the increasing waste loads which will be imposed on the waste treatment facilities point out the need for the adoption and implementation of a comprehensive program for water pollution control in the Green Bay Area. The program of necessity must emphasize construction of new and enlarged sewerage facilities, proper operation of new and existing facilities, and intensive and continuous monitoring of operation, waste treatment efficiency and water quality.

RECOMMENDED ACTIONS

1. All municipal waste treatment facilities should be designed and operated to provide secondary (biological) waste treatment and to achieve an overall reduction in untreated BOD_5 of 90 percent or higher, on a continuous basis. The major municipal plants and needed improvements are listed in Table 7-1.

2. Continuous disinfection should be provided for all municipal waste treatment plant effluents in the study area.

3. All separately discharging industrial wastes should receive the equivalent of secondary treatment, as described above. Where practicable, industrial wastes should be discharged to municipal sewerage systems. The major industries needing improvements are listed in Table 7-2.

4. Sanitary sewage discharged from industries should receive the same treatment as recommended for municipal wastes.

5. Maximization of phosphate removal, through modification in the operation and/or design of existing and newly constructed secondary waste treatment facilities should be an immediate objective. Records of phosphorus removal at the treatment plants of the Green Bay Area should be carefully evaluated after one year to determine if significant phosphorus removals have been achieved. If such removals are not achieved, consideration should be given to the installation of chemical precipitation facilities at such plants.

6. Combined sewers should be prohibited in all newly devoloped urban areas and should be separated in coordination with urban renewal projects. Existing combined sewer systems should be patrolled and overflow regulating devices should be adjusted to convey the maximum practicable amount of combined flow to treatment facilities.

7. The operation of hydropower installations should be reviewed to ensure the maximum practicable streamflow through the facility at all times.

8. Streamflow regulation may be necessary in the Lower Fox River even after a high degree of waste treatment is put into effect, if the desired water quality goals are to be met. However, streamflow regulation is not to be considered as a substitute for the waste treatment improvement measures recommended herein.

9. Agricultural practices should be reviewed to ensure the maximum protection of the waters of the Green Bay Area from the improper application of fertilizer and pesticides.

10. The Water Pollution Control Agencies of the States of Michigan and Wisconsin should conduct waste treatment plant inspections at least annually for small and medium-sized plants, and at least twice annually for the larger plants.

11. Monthly reports covering the operation of all municipal and industrial waste treatment plants including the quality and quantity of discharged effluent should be submitted to the Water Pollution Control Agencies of the States of Michigan and Wisconsin.

12. All industries and municipalities and other agencies discharging wastes into the waters of the Green Bay Area should submit, within six months to the appropriate State agency, a report containing a time schedule for completion of any new construction, modifications to any existing structures, process changes or operating procedures necessary to meet the above recommendations.

13. The adoption of a mandatory sewage treatment plant operators' certification program in Wisconsin is recommended. Operation training courses should be offered annually.

14. The water quality monitoring programs of the Michigan and Wisconsin Water Pollution Control Agencies in the Green Bay Area should be strengthened. The program should be geared to indicate change or trends in water quality and the need for additional quality improvement measures.

15. It is recommended that the water pollution control activities in Michigan and Wisconsin be strengthened in terms of staffing and budget. With additional resources and the support available from the Administration the implementation of the program outlined herein and similar programs in other Basins throughout the States can be accelerated to meet the growing need for clean water.

CHAPTER I

INTRODUCTION

Purpose

This report presents an action program of water pollution control, geared to provide high quality waters in the Green Bay Watershed through abatement of existing pollution, and to provide continuing control of pollution through preventive actions scheduled in anticipation of future problems. This report and resulting program have been developed from both extensive and intensive information on present water quality, water uses and trends in water usage, present and anticipated future waste loads, the existing and projected population and economic growth, and other relevent facts gathered by the Great Lakes-Illinois River Basins (GLIRB) Project, Federal Water Pollution Control Administration, Department of the Interior, during its study of the Great Lakes Basin.

Scope

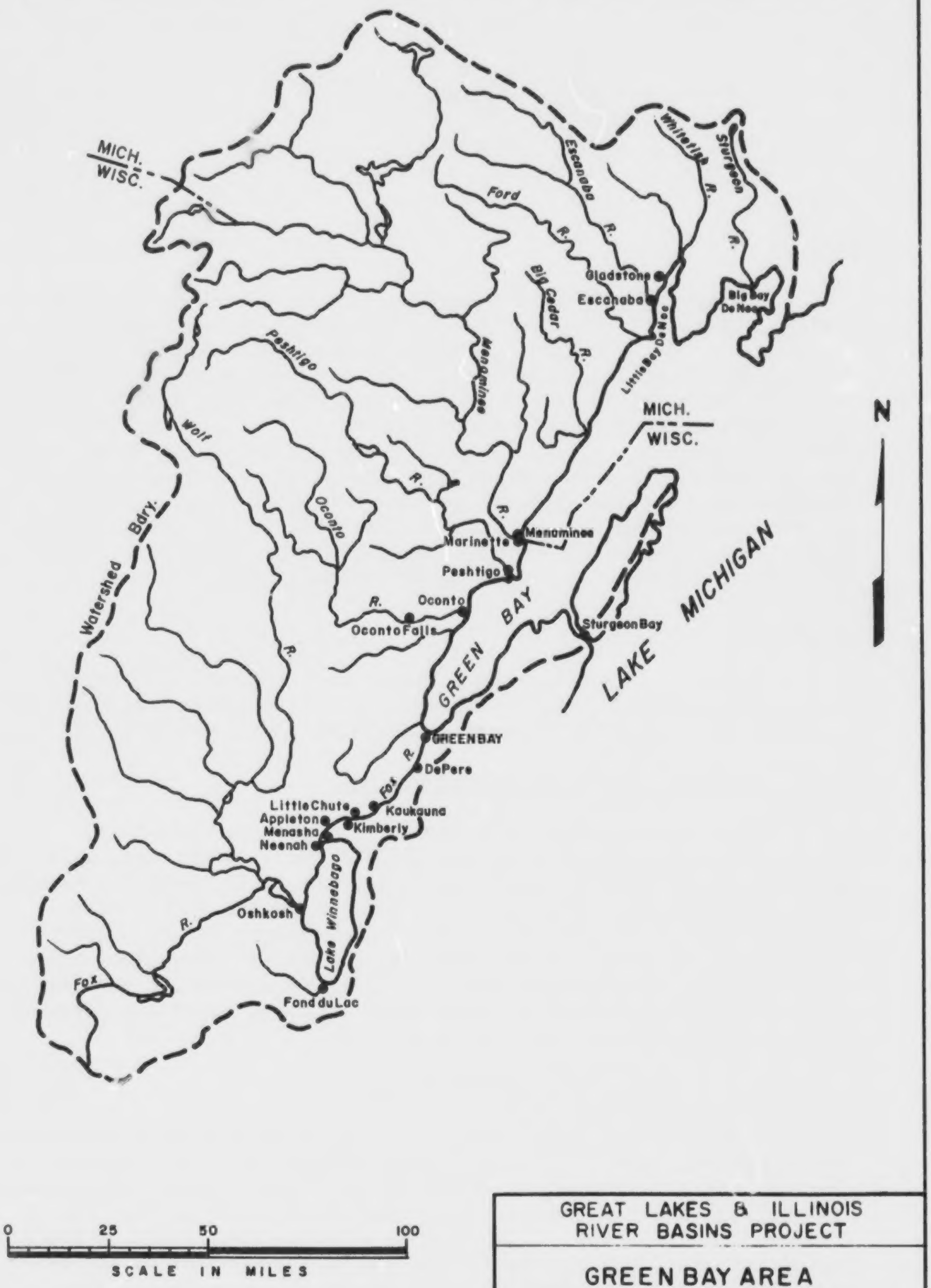
The area (See Figure 1-1) within the scope of this report includes the waters of Green Bay and the entire watershed tributary to Green Bay in both the States of Michigan and Wisconsin.

Great Lakes-Illinois River Basins Project

This report is one in a series of 7 proposed documents (Table 1-1) being prepared by the GLIRB Project at Chicago, Illinois. When completed these 7 reports taken together will present a comprehensive program for water pollution control in the entire Lake Michigan Basin. In addition to the Lake Michigan Basin, GLIRB Project with program offices currently located at Cleveland, Ohio, Rochester, New York and Detroit, Michigan, is developing similar programs for the watersheds of Lakes Erie, Ontario, Huron and Superior and the Illinois River Basin (Figure 1-2).

Authority

Comprehensive water pollution control studies were authorized by the Federal Water Pollution Control Act of 1956, as subsequently amended. Inititation of the Great Lakes-Illinois River Comprehensive Program Activity followed an appropriation of funds by the 86th Congress late in 1960. In accordance with the provisions of the Act the Secretary of Health, Education, and Welfare delegated the responsibility for the study to the Division of Water Supply and


MICH.
WISC.
Escanaba R.
Whitefish R.
Sturgeon R.
Ford R.
Big Cedar R.
Gladstone
Escanaba
Big Bay De Noc
Little Bay De Noc
Menominee R.
Peshtigo R.
Wolf R.
Oconto R.
MICH.
WISC.
N
Menominee
Marinette
Peshtigo
Oconto
Oconto Falls
GREEN BAY
Sturgeon Bay
LAKE MICHIGAN
Watershed Bdry.
GREEN BAY
Fox R.
DePere
Little Chute
Kaukauna
Appleton
Kimberly
Menasha
Neenah
Oshkosh
Lake Winnebago
Fox R.
Fond du Lac
0
25
50
100
SCALE IN MILES

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

**GREEN BAY AREA
MICHIGAN AND WISCONSIN**

U.S. DEPT. OF HEALTH, EDUCATION, & WELFARE
FEDERAL WATER POLLUTION CONTROL ADMIN.
REGION V CHICAGO, ILLINOIS

FIGURE 1-1

TABLE 1-1

GREAT LAKES-ILLINOIS RIVER BASINS PROJECT

COMPREHENSIVE WATER POLLUTION CONTROL PROGRAM FOR THE LAKE MICHIGAN BASIN

Tentative Program Reports

Green Bay Area, Michigan and Wisconsin

Milwaukee Area, Wisconsin

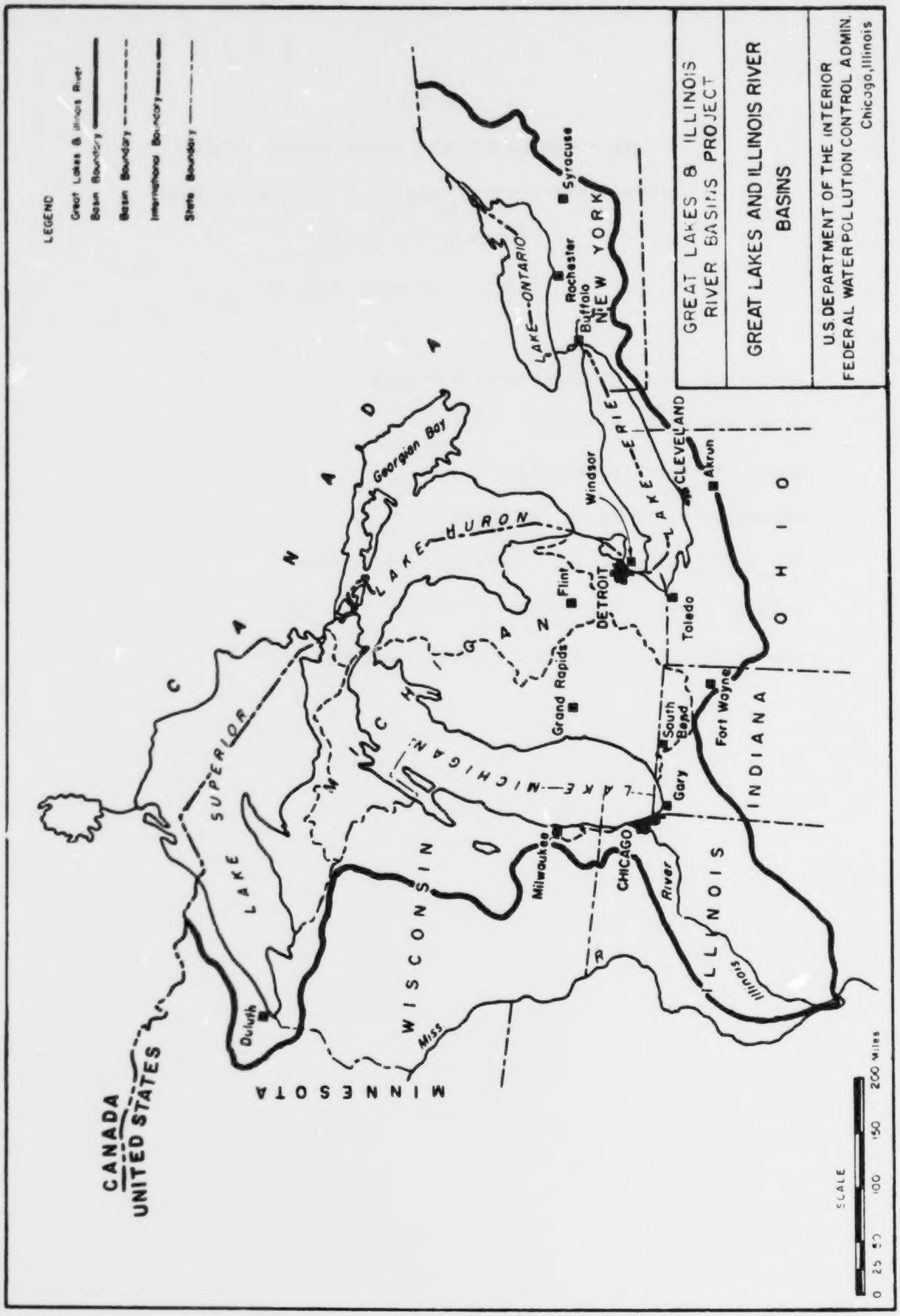
Grand River Basin, Michigan

Kalamazoo River Basin, Michigan

St. Joseph River Basin, Indiana and Michigan

Calumet Area, Illinois and Indiana

Lake Michigan and Tributary Areas (Summary Report)



LEGEND
Great Lakes & Illinois River Basin Boundary
Basin Boundary
International Boundary
State Boundary
CANADA
UNITED STATES
MINNESOTA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
NEW YORK
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
Georgian Bay
Duluth
Milwaukee
CHICAGO
Gary
South Bend
Grand Rapids
Fort Wayne
Flint
DETROIT
Windsor
Toledo
CLEVELAND
Akron
Buffalo
Rochester
Syracuse
Illinois River
Miss R
SCALE
0 25 50 100 150 200 Miles

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

GREAT LAKES AND ILLINOIS RIVER
BASINS

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Chicago, Illinois

FIGURE 1-2

Pollution Control of the Public Health Service. Passage of the "Water Quality Act of 1965" gave the responsibility for these studies to the Federal Water Pollution Control Administration. As a result of Reorganization Plan No. 2 of 1966 the FWPCA was transferred from the Department of Health, Education, and Welfare to the Department of the Interior effective May 10, 1966.

Organization

Following the initial appropriation of funds by Congress in 1960, a task force designated the GLIRB Project was organized to conduct the study. Project headquarters are located at 1819 West Pershing Road, Chicago, Illinois. Its permanent staff includes specialists covering a broad gamut of professional skills, including sanitary and hydraulic engineers, chemists, biologists, bacteriologists, radiochemists, oceanographers and economists. The Project has drawn freely on the resources of the Robert A. Taft Sanitary Engineering Center at Cincinnati, Ohio. Valuable counsel and advice have been received from a Technical Committee appointed by the Surgeon General of the Public Health Service. This Committee is composed of men in responsible positions in State water resource and water pollution control agencies, municipal water and sewer departments, private research organizations, conservation groups, and industry. Table 1-2 gives the names and positions of the Technical Committee Members.

Cooperative Program

As required by the authorizing legislation the GLIRB Project has worked closely with other Federal, State and local agencies to develop a comprehensive water pollution control program. A list of the principal agencies which have participated through preparation of special reports or through their release of supporting information is as follows:

- Illinois
    - State Sanitary Water Board
    - Department of Public Health

- Indiana
    - Stream Pollution Control Board
    - State Board of Health

- Michigan
    - State Water Resources Commission
    - Department of Health

- Wisconsin
    - Committee on Water Pollution
    - Board of Health

U. S. Federal Power Commission

U. S. Department of the Army
  Corps of Engineers

U. S. Department of the Interior
  Bureau of Commercial Fisheries
  Bureau of Outdoor Recreation
  Bureau of Sport Fisheries and Wildlife
  Geological Survey

U. S. Department of Commerce
  Weather Bureau
  Office of Business Economics

TABLE 1-2

TECHNICAL COMMITTEE TO THE GREAT LAKES-ILLINOIS RIVER BASINS PROJECT
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TABLE 1-2 (Cont'd.)

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Assistant to the Vice President
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1330 West Michigan Street
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CHAPTER 2

DESCRIPTION OF AREA

Geography

The watershed tributary to Green Bay contains a total drainage area of approximately 15,000 square miles or about one-third of the total Lake Michigan Basin. Approximately two-thirds, or 10,000 square miles, of the study area lies within the State of Wisconsin. The remainder of the drainage area or approximately 5,000 square miles is within the State of Michigan.

Hydrology

Green Bay is approximately 118 miles long and has a mean width of 23 miles. The mean depth is about 65 feet. There are five major streams and a large number of minor streams draining into Green Bay as shown in Figure 1-1. The five major streams are the Fox River, the Oconto River, the Peshtigo River, the Menominee River and the Escanaba River. The drainage areas for the major streams are shown in Table 2-1.

TABLE 2-1

Drainage Areas - Major Tributaries
of Green Bay

Stream	Length of Stream(mi.)	Drainage Area(sq.mi.)
Fox	200	6,443
Menominee	120	4,150
Peshtigo	145	1,155
Oconto	130	933
Escanaba	115	920

The Fox River, the largest stream in the Lake Michigan Basin, is located in the northeastern part of Wisconsin. Its principal tributary is the Wolf River with a drainage area of 3,780 square miles. The Fox River Basin is irregular-shaped with a maximum north-south dimension of about 150 miles and a maximum width of 75 miles.

The Menominee River is formed by the confluence of the Brule and Michigamme Rivers near Florence, Wisconsin. The Menominee River continues as the state boundary flowing in a southeasterly direction for about 115 miles to the Menominee, Michigan-Marinette, Wisconsin area, where it enters Green Bay.

The Peshtigo River originates in the central part of Forest County, Wisconsin. The stream is oriented so as to flow to the southeast and discharges into Green Bay at a point about 7 miles southeast of Peshtigo. The overall length of the drainage area is about 80 miles with an average width of about 14 miles.

The Oconto River originates in a number of small lakes in Forest County, Wisconsin. The stream is oriented in a northwest to southeast direction and drains into Green Bay at a point about 3 miles east of Oconto. The overall length of the drainage area is about 65 miles and it has an average width of 15 miles.

The U. S. Geological Survey maintains 41 stream gaging stations within the study area.(1,2) The gaging stations are distributed in the major river basins of the study area as follows:

River Basin	No. of Gaging Stations
Fox	11
Oconto	3
Peshtigo	1
Menominee	9
Escanaba	8

The mean and pertinent low streamflows as observed at the long-term stations located on the major streams and closest to Green Bay are shown in Table 2-2.

TABLE 2-2

Streamflow Records(1,2,3,4)
Green Bay Study Area

Gaging Station	Drainage Area(sq.mi.)	Minimum Flow(cfs)	7 day,1-in-10-yr. Low Flow (cfs)	Mean Flow(cfs)
Fox River near Wrightstown, Wis.	6,150	138	820	4,149
Oconto River near Gillett, Wis.	678	93	180	569
Peshtigo River at Peshtigo, Wis.	1,124	32	-	825
Menominee River below Koss, Mich.	3,790	162	780	3,096
Escanaba River at Cornell, Mich.	870	90	160	899

Topography and Soils

The topography of the study area was formed by glaciers which covered the area a number of times. Much of the area has rugged topography, while some small areas are rolling to hilly. The highest point in the study area, elevation 1,850, is located near Iron River, Michigan in the northwest section of the drainage area. The land near Green Bay (elevation 600-700 feet above sea level) is very flat, while the area located in the higher elevations to the north and west of Green Bay is rolling.

Two general soil groups are located in the watershed area north and northwest of Green Bay and extending south to the Fox River Basin. The soil is poorly to imperfectly drained, slightly acid to neutral, with a loam or very fine loam surface associated with wet acid peats. Where the glacial drift is shallow there are rock knobs. In some landscapes gravelly or stony soils predominate but in others they are associated with sandier or more loamy soils. Approximately 80% of the soil of the area consists of this group.

Climate

The average annual temperature throughout the watershed is about 45°F. Mean monthly temperatures range from a low of approximately 17°F in January to 71°F in July. Mean monthly precipitation ranges from a low of about 1 inch in January to a high of 4 inches in June, with an average annual precipitation of 29 inches. Most of the precipitation occurs from May to September. The period of December through March is the time of lowest precipitation.(5,6).

Population

The 1960 population of the study area was approximately 710,000. The total municipal population was approximately 63% of this figure. Major cities in the study area and their 1960 population are shown below in Table 2-3.

TABLE 2-3

Population of Major Cities

City	1960 Population
Green Bay, Wisconsin	62,888
Appleton, Wisconsin	48,411
Oshkosh, Wisconsin	45,110
Fond du Lac, Wisconsin	32,710
Neenah, Wisconsin	18,057
Menasha, Wisconsin	14,647
Marinette, Wisconsin	13,329
Escanaba, Michigan	15,391
Menominee, Michigan	11,289

As shown in Table 2-4 the study area population is projected to increase approximately two-fold by 2020 at which time it is estimated that 80% of the population will be municipal.

TABLE 2-4

Population Projections
Green Bay Study Area

Year	1960	1980	2020
Total Watershed Population	710,000	870,000	1,450,000
Estimated Municipal Population	448,000	590,000	1,150,000
Percent of Total Population that is Municipal	63%	68%	80%

Economy

Some elements of the economy which make demands upon the water resources of the study area are manufacturing, agriculture, commerce, mining, and the tourist and resort industry.

Manufacturing

The manufacture of paper and allied products is the major industry in the study area.(7) Analysis of the area's economy indicates that this industry is likely to remain as the dominant manufacturing activity in the study area in the future.

Other significant industries in the area produce food and kindred products and non-electrical machinery.

The total value added by manufacture (VAM) for the Green Bay area was greater than $640,000,000 (constant 1957-1959) in 1958. A study of economic indices indicates that an approximate doubling in manufacturing is expected by the year 1980. The rate of growth beyond that date also looks encouraging. Due to water reuse and other efficiencies the demands for water are expected to increase at a more moderate pace. These factors are used in evaluating the estimates of future industrial water use and waste loads in Chapters 3 and 4.

Agriculture

Approximately 20% of the watershed area is in farm land. The sales of crops, livestock and livestock products exceeded 180 million dollars in 1959. The majority of these agricultural activities take place in the southern portion of the watershed area, i.e., the Wolf and Fox River Basins. Approximately 85% of the agricultural income results from the sale of livestock and livestock products. Major crops raised in the area include fruits, potatoes, and other vegetables. Dairy products are also important.

Commerce

Green Bay at the mouth of the Fox River is the most important commercial center in the study area and the major center in the northwest Lake Michigan Basin. There are several commercial harbors in Green Bay engaged in interstate trade and in international trade through the St. Lawrence Seaway. See Chapter 3 for a fuller discussion of the water use.

Mining

The value of mineral production of this area is greater than any other area in the Lake Michigan Basin. In 1959, the value of iron ore production totaled $18.9 million in Iron County, Michigan. The iron formations of the Menominee Range also extend into Florence County, Wisconsin.

Tourism

Green Bay area including Little and Big Bays De Noc and the Door Peninsula, is important from a recreational use standpoint. The fishery of Green Bay is of particular significance, having been called by some the "Walleye Capitol of the World." In addition, the numerous public parks, lakes, and boat harbors of the study area coupled with its relatively low population density will continue to make the Green Bay area an important haven for tourists.

CHAPTER 3

WATER USES AND WATER QUALITY GOALS

Water Uses

The principal water uses in the Green Bay Area include:

- Municipal water supply.
- Self-supplied industrial water.
- Recreation.
- Irrigation.
- Fish and Aquatic Life.
- Wildlife and stock watering.
- Hydropower.
- Commercial shipping.
- Cooling water supply.
- Waste assimilation.
- Esthetics.

Table 3-1 indicates the water use sectors determined for the study area. The sector boundaries were based on a consideration of changing water quality, changes in water uses or certain physical features of the area and were developed in cooperation with States of Michigan and Wisconsin. The major water uses of the area are discussed in the following sections of this Chapter.

Municipal Water Supply

Eighty three municipalities within the study area were served by municipal water supply systems as of 1962. The total number of persons served by these facilities is approximately 65 percent of the study area population. Table 3-2 summarizes water use data for the Green Bay Area. Municipal demand totaled 54 mgd (million gallons daily).

TABLE 3-2

TOTAL WATER DEMAND - GREEN BAY AREA

Source	Population Served	Water Demand (mgd)	Per Capita Water Demand Gals. per day
Surface Water	263,000	35	133
Ground Water	189,000	19	100
Totals	452,000	54	120

TABLE 3-1

WATER USES BY SECTORS, FOX RIVER-GREEN BAY AREA (8)

Water Uses	Green Bay	Fox River			Oconto River		Peshtigo River		Ford River	Menominee River				Escanaba River	Whitefish River	Sturgeon River
	1	1	2	3	1	2	1	2	1	1	2	3	4	1	1	1
Municipal Water Supply	P*	P*	P	-	-	-	-	-	A	-	-	-	-	A	A	A
Industrial Water Supply	P*	P*	P	A	-	P	-	P	A	P	P	P	-	P	-	-
Recreation																
Whole Body Contact	P*	-	P	P	P*	P	-	P	P	-	P	P*	P	P*	P	P
Partial Body Contact	P*	P*	P	P	P*	P	P*	P	P	P*	P	P*	P	P	P	P
Irrigation Water Supply	P*	P	P	A	P	-	-	P	-	-	-	-	P	-	-	-
Fish-Pollution																
Tolerant	P*	P*	P	P	P*	P	P*	P	P	P	P	P*	P	P*	P	P
Facultative	P*	-	P	P	P*	P	P*	P	P	P	P	P*	P	P*	P	P
Intolerant	-	-	-	P	-	P	-	P	P	P*	P	P*	P	P*	P	P
Wildlife and Stock Watering	P*	-	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Hydropower	-	P	-	-	P	P	-	P	-	-	P	P	P	P	-	-
Commercial Shipping	P	P	P	-	-	-	-	-	-	P	-	-	-	-	-	-
Cooling Water Supply	P*	P*	P	A	-	-	-	P	-	P	P	P	-	P	-	-
Waste Assimilation	P	P	P	P	P	P	P	P	P	P	P	P	P	P	-	-
Esthetics	P*	P*	P	P	P	P	P	P	P	P*	P	P*	P	P	P	P

P = Present use and anticipated future use.
A = Anticipated future use.

- = Neither Present or Anticipated.
* = Use presently adversely effected by pollution.

TABLE 3-1 (Cont'd)

Sector Description.

River	State	Sector	Description
Fox	Wisconsin	1	Green Bay to Lake Winnebago.
		2	Lake Winnebago to Omro, Wisconsin.
		3	Omro, Wisconsin to Headwaters.
Oconto	Wisconsin	1	Green Bay to dam at Oconto Falls, Wisconsin.
		2	Dam at Oconto Falls, Wisconsin to Headwaters.
Peshtigo	Wisconsin	1	Green Bay to Peshtigo Dam.
		2	Peshtigo Dam to Headwaters.
Menominee	Michigan and Wisconsin	1	Green Bay to dam at Marinette, Wisconsin
		2	Dam at Marinette, Wisconsin to County 2 Bridge.
		3	County 2 Bridge to just above Iron Mountain, Michigan.
		4	Just above Iron Mountain to Headwaters.

NOTE: The number 1, alone, indicates that the entire body of water has been considered as one sector.

Table 3-3 gives details of water use information for principal municipalities. The table includes projections for major water service areas to the years 1980 and 2020.

Industrial Water Supply

The major demand for self-supplied industrial water occurs in the general areas shown in Table 3-4. Projections contained in the table were developed following consideration of anticipated increases in industrial activity and water use efficiency factors.

Recreation

The Bureau of Outdoor Recreation (BOR) and the Bureau of Sport Fisheries and Wildlife both of the Department of the Interior have prepared reports concerning the recreational, fish, and wildlife aspects of the Lake Michigan Basin. (9,10) The BOR has estimated that the annual pressure on the entire Lake Michigan Basin as a whole was 176,000,000 activity days for water-oriented and water related recreation. Projections indicate that water oriented recreation in the Lake Michigan Basin may well increase more than threefold by the year 2000.

Green Bay including Little and Big Bays de Noc and the Door Peninsula is highly important from a recreational use standpoint. The users of the larger pleasure boats find the Green Bay area ideal for their purposes. Approximately 7,000 recreational boats use the waters of the Bay during the boating season. It is large enough area to be challenging to their boats and boating ability, yet it is safer than the main body of Lake Michigan. Thus the Green Bay-Bay de Noc area is becoming a mecca for the weekend sailor.

While the Lower Fox River is no longer used for commercial boating, some 1,000 boats passed through the locks on some part of the River in 1963, indicating the use of this area by pleasure craft.

Recreational use of southern Green Bay has been limited considerably due to pollution for many years. Swimming at Bay Beach Park on the east Bay shore has been prohibited by the Green Bay Health Department for approximately 25 years. All types of fishing in the Green Bay City vicinity are now virtually non-existent, due to pollution.

Irrigation

The present (1960) water usage for irrigation in the Green Bay study area is estimated to be approximately 12 mgd on the average during the growing season. Irrigation is most extensive in the Fox River watershed. (11) It is anticipated that this usage will increase threefold by 1980. While irrigation plays no significant role in the water quality problems described in Chapter 6, it is a use that bears

TABLE 3-3

SUMMARY OF MUNICIPAL WATER SUPPLIES(1) AND PROJECTED INCREASES IN WATER USAGE IN PRINCIPAL SERVICE AREAS

GREEN BAY WATERSHED AREA

Location	Source Wells-W Surface-S	Population Served (1962)	Demand 1962 (MGD)	Demand 1980 (MGD)	Demand 2020 (MGD)
		Michigan			
Negaunee	S	6,100	1.14		
Gladstone	S	4,800	0.62		
Escanaba	S	15,400	1.72	3.9	4.1
Iron Mountain - Kingsford	S	15,000	1.41		
Menominee	S	11,000	1.5		
		Wisconsin			
Marinette	S	14,000	1.8		
Menominee-Marinette Area	S			5.0	5.0
Green Bay	S	66,000	9.4		
Green Bay Area (2)	W&S		12.8	23	63
Appleton	S	52,700	6.16		
Appleton Area (3)	W&S		16.3	27	63
Neenah	S	19,700	3.50		
Menasha	S	15,300	4.55		

TABLE 3-3 (Cont'd)

Location	Source Wells-W Surface-S	Population Served (1962)	Demand 1962 (MGD)	Demand 1980 (MGD)	Demand 2020 (MGD)
Preble, S.D.	W	12,500	0.81		
De Pere	W	11,200	1.84		
Kaukauna	W	10,400	0.80		
Oshkosh	S	46,300	4.20		
Fond Du Lac	W	33,600	3.20		

(1) Municipal demand includes industrial water supplied by the municipal supply.

(2) Includes Green Bay, Allouez, Ashuabenon, De Pere, and Preble, Wisc.

(3) Includes Kaukauna, Kimberly, Little Chute, Appleton, Neenah, and Menasha, Wisconsin.

TABLE 3-4

SELF-SUPPLIED INDUSTRIAL WATER DEMAND
(MGD)

Area	1959	1980	2020
Lower Fox River(1)	127	214	344
Oshkosh	14	20	38
Marinette-Menominee	43	63	78
Escanaba	5	6	9

(1) Includes: Neenah, Menasha, Appleton, Kaukauna,
De Pere, and Green Bay

watching in terms of water demands during low stream flow conditions particularly as the irrigation demand increases in the future.

Fish and Aquatic Life

The cleaner central and northern waters of Green Bay and its tributaries support a wide variety of fish. Important species include trout, smallmouth bass, walleyed pike, northern pike and panfish. Little and Big Bays de Noc are cited as being particularly important from a fishery standpoint. The tributary fishery is important for recreational use while the waters of Green Bay are important from both a recreational and a commercial standpoint. (10,13)

Lake Michigan's western shore plays an interesting role in the migration pattern of many bird species. The protection afforded by this area causes many waterfowl and shorebirds to concentrate along this extensive north-south coast, especially during periods of seasonal migration. The southwest and west shores of Green Bay for example are areas of shallow water containing a variety of desirable aquatic plants which provide suitable habitat for migrating fowl. Further south, however, the polluted discharges from the Fox River are creating conditions unfavorable to these aquatic plants.

Wildlife and Stock Watering

The present (1960) agricultural water use for stock watering in the Green Bay watershed is approximately 9 mgd. (11,12) Projections of this usage indicate that the demand will more than double by 2020. This particular water usage does not plan a significant role in the water quality problems described in Chapter 6.

Hydropower

There are 37 hydroelectric installations in the Green Bay study area. These plants have an installed capacity of approximately 200,000 kilowatts (KW). Plant locations are summarized in Table 3-5 by river basin.

TABLE 3-5

HYDROELECTRIC INSTALLATIONS
GREEN BAY WATERSHED

River Basin	Number of Installations	Approximate Capacity KW
Escanaba	5	12,000
Menominee	15	110,000
Peshtigo	5	22,000
Oconto	3	3,500
Fox	9	25,000

There are approximately 26 potential hydroelectric sites which, if developed, would provide an additional 120,000 KW capacity.

Under low stream flow conditions the operation of these installations can seriously effect downstream water quality. Wisconsin laws require that a minimum of 25% of the stream flow be passed through the facilities at all times. Michigan has no such requirements. As can be seen from the Chapter 6 discussion of present water quality problems, releases from these installations may be inadequate under low flow conditions to maintain desirable downstream water quality conditions.

Commercial Shipping

There are several commercial harbors in the Green Bay Area. The St. Lawrence Seaway has made world ports of the cities adjoining Green Bay. Commercial shipping cargoes at the City of Green Bay consist primarily of plywood, veneers, pulpwood, and iron and steel products. Green Bay Harbor is located on Green Bay at the mouth of the Fox River. The widened channel in the Fox River is 24 feet deep to a point beyond the Chicago and North Western Railway bridge and 19 feet deep to De Pere. This channel also has three turning basins. The Fox River provides a channel 6 feet deep from De Pere to the mouth of the Wolf River. Traffic in this section has declined in recent years; no commercial traffic was reported in 1963.

Menominee-Marinette Harbor is located at the mouth of the Menominee River. Waterborne commerce at Menominee Harbor consists primarily of car-ferry traffic and the receiving of coal and limestone. Car-ferry steamers operate throughout the year between this port and Frankfort, Michigan.

Escanaba Harbor is situated on the west shore of Little Bay de Noc. Extensive ore docks and wharves have been built and slips adjacent thereto have been provided by railway and other corporations. This Harbor moves more tons of traffic than any other harbor in the Green Bay Area.

Gladstone Harbor is located on the western shore of Little Bay de Noc about eight miles north of Escanaba. Petroleum products are the major items of traffic.

A summary of 1964 vessel traffic in the various ports of Green Bay is given below in Table 3-6.

TABLE 3-6

VESSEL TRAFFIC, GREEN BAY AREA

Port	Vessel Traffic (Tons)	Vessel Movements
Green Bay, Wisc. (Includes De Pere)	2,516,659	988
Menominee, Michigan-Marinette, Wisconsin	453,553	480
Escanaba, Michigan	7,707,940	1,108
Gladstone, Michigan	278,849	188

By 1980 and 2020 this tonnage is expected to increase somewhat, however, the actual number of ship movements may be expected to remain approximately the same due to anticipated increase in vessel size.

Cooling Water

Thermo-electric generating installations exert a major demand for cooling water. There are 27 such plants in the Green Bay Watershed. These plants have a total installed capacity of just under 500,000 KW and require an estimated 700 MGD for cooling purposes. Thirteen of these plants are located along the Fox River from Lake Winnebago to Green Bay. The waste heat from these plants intensify the water quality problems along the Lower Fox River as discussed in Chapter 6. On the average water passing through the cooling condensers of such installations raise the incoming water temperature some 12-13°F on a once through basis.

Waste Assimilation

Use of streams in the Green Bay Basin for waste assimilation is one of the predominant present day uses, and in several locations the cause of extreme problems in water pollution control. These will be discussed in Chapters 4 and 6.

Esthetics

Since the esthetic appearance of streams and lakes is an intangible quantity there are no numerical factors by which it can be rated. It is, nevertheless, a very important factor in determining the recreational potential of the Fox-Green Bay Area. Camping, picnicking, sightseeing, while not directly water-oriented activities, are considerably enhanced as an experience by esthetically pleasing water. Pollution robs the water of its esthetic value for such activities.

Since this area will be called upon to provide recreation for many people from out of this area it is very important that the area and the waters of the area be kept esthetically pleasing. It is also important, if not more important, that the area is attractive and remains so to those people who live there every day of the year.

Water Quality Goals

The preceding discussion of water uses now being practiced as well as the anticipated growth of these uses presupposes that adequate water, both in quantity and quality, will be available to accommodate them. Quantity factors have already been prescribed in Chapter 2. Quality factors require consideration of both technical needs of the water uses to be accommodated and judgment with respect to compatibility of water quality requirements of competing water uses. The development of Water Quality Criteria is a first step in the development of the quality factors needed in water pollution control.

The establishment of water quality criteria for the significant water uses of the Lake Michigan Basin was accomplished through the organization of four water quality work groups chaired by a member of the Technical Committee shown in Table 1-2. These work groups consisted of representatives of the states, municipalities and industries of the Lake Michigan Basin.

These four work groups, The Municipal Work Group; The Industrial Work Group; The Fish, Aquatic Life, and Recreation Work Group; and the General Work Group considered water quality needs to support eleven specific water uses, namely:

Municipal Water Supply
Industrial Water Supply
Recreation - Whole and Partial Body Contact
Irrigation
Fish and Aquatic Life
Wildlife and Stock Watering
Hydropower
Commercial Shipping
Cooling Water Supply
Waste Assimilation
Esthetics

The criteria developed by the four work groups give maximum or minimum desirable concentrations of various water quality parameters, above or below which the stated water uses would be adversely affected. Limits were not set for all water quality parameters but rather for those parameters which are generally most significant in the Lake Michigan Basin. The findings of the water quality work groups are summarized in Table 3-7. Minimum dissolved oxygen requirements and maximum coliform, phosphate, phenol, and ammonia nitrogen concentrations are most pertinent to water quality problems within the study area.

In the study area there are certain sectors in which specific uses discussed in this Chapter are being jeopardized. The affected are indicated on Table 3-1 by means of an asterisk. In these sectors, where pollution is adversely affecting water quality to the extent that the established water quality criteria are not met, the criteria become the water quality goals to be met by pollution control measures. Further discussion of the water quality problems in the study area is contained in Chapter 6. These areas will be protected through the comprehensive water pollution control action program for the Green Bay Area outlined in Chapter 9.

TABLE 3-7
LAKE MICHIGAN BASIN - WATER QUALITY CRITERIA FOR SPECIFIC WATER USES (5)
Numerical Values in Columns

WATER USE	WATER QUALITY PARAMETER (Maximum or Minimum Concentrations For Any One Sample																	
	DO (min) mg/1 or % Saturation	pH (Range)	Phenolics (max) mg/1	Chloride (max) mg/1	MBAS (Max) mg/1	Turbidity Units (max)	Temperature °F (max)	Color Units (max)	Coliform Guide (1) (max)	BOD$_5$ (max)mg/1	NH_3-N (max) mg/1	Dissolved Solids (max) mg/1	Cyanide CN^- (max) mg/1	Iron (Fe^{++}) (max) mg/1	Manganese (max) mg/1	Odors (max) (Threshold No.)	Phos. Soluble (PO_4)(max) mg/1	Sulfate (SO_4) (max) mg/1
Municipal Water Source	80	7.7 9.0	.003	20	0.2			15	C		0.1	186	0.1	0.3		(2)	.03	50
Industrial Process Water	1.0	5 9	1.0	250	1.0	250	80	100	D	10	5	750		0.2	0.1			
Recreational-Whole Body Contact	3.0					50	90	50	A									
Recreational-Limited Body Contact			1.0			250	90		B									
Irrigation																		
Fish and Aquatic Life-Tolerant	3.0	6 9	0.2	500	1.0	50	90											
Fish and Aquatic Life-Facultative	4.0	6 9	0.2	500	1.0	50	87											
Fish and Aquatic Life-Intolerant	6.0	6 9	0.2	500	1.0	50	68											
Wildlife and Live-Stock Watering		5 9		2000		250												
Hydroelectric Power		5 9				250												
Commercial Shipping		5 9				250												
Cooling		5 9		700		250	90											
Esthetics	1.0				1.0													
Waste Water Assimilation	1.0	5 9					110											

(1)
(2) See Following Pages

TABLE 3-7 (Continued)

(1) Coliform Guides

Coliform Guide A - Recreational whole body contact use. The water uses for which this guide is intended are those that entail total and intimate contact of the whole body with the water. Examples of such use are swimming, skin diving, and water skiing, in which the body is totally immersed and some ingestion of the water may be expected. Recommended guide value for coliforms is 1,000 per 100 milliliters (1,000/100 ml). For all waters in which coliform levels are below the guide value of 1,000/100 ml, the water is considered suitable provided there is proper isolation from direct fecal contamination as determined by a sanitary survey. Situations may arise wherein waters having coliform counts somewhat higher than the guide value can be used, provided supplemental techniques are used to determine safe bacterial quality. The analysis for fecal streptococci is more definitive for determing the presence of organisms of intestinal origin, and is suggested as the supplemental technique to be employed. Based on a very limited amount of information, a limit for fecal streptococci of about 20/100 ml is suggested providing there is an accompanying limit on the coliform level. As a provisional limit, it is suggested that a coliform level of 10,000/100 ml be permitted provided the fecal streptococcus count is not more than 20/100 ml, and provided also that there is proper isolation from direct fecal contamination as determined by a sanitary survey.

Coliform Guide B - Recreational, limited body contact use and commercial shipping (barge traffic). The water uses for which this guide is intended are those that entail limited contact between the water user and the water. Examples of such uses are fishing, pleasure boating, and commercial shipping. Recommended guide value for coliforms is 5,000/100 ml. For all waters in which coliform levels are below this guide value, the water is considered suitable for use, provided there is proper isolation from direct fecal contamination as determined by a sanitary survey.

For waters which have coliform levels above the guide value and such levels are evidently caused primarily by organisms of other than fecal origin, the limiting count may be as high as 50,000/100 ml, provided the fecal streptococci count is not more than 100/100 ml. The provisional coliform limit of 50,000/100 ml is based on an examination of reported and measured data for the Illinois River Basin streams. It is believed to be an acceptable limit for taking into consideration, and providing for the occurrence of, background coliform levels. With the accompanying limit on fecal streptococci, it is reasonable to expect that the danger of infection by enteric organisms

TABLE 3-7 (Continued)

will be remote. It is understood that the provisional limit would be subject to modification as more analytical data are accumulated and critically reviewed.

Coliform Guide C - Applies to Municipal Water Source. Where municipal water treatment includes complete rapid-sand filtration or its equivalent, together with continuous postchlorination, source water may be considered acceptable if the coliform concentration (at the intake) averages not more than 5,000 per 100 ml in any one month, and the count exceeds this number in not more than 20 percent of the samples in any one month. Samples should be tested at least once daily.

Coliform Guide D - Applies to Industrial Process Water at the source. Although the requirements of this use will vary widely with the processes of a particular industry, Coliform Guide C, for municipal source, is considered generally applicable. As covered by food and drug acts and other regulations, water incorporated into products for human ingestion should, of course, meet finished drinking water standards.

(2) Odors, Threshold Number

The differences in type of odors makes it difficult to assign numbers for water quality goals with respect to this parameter. For some types of odors the difficulty of removal is greater than for others. To reach acceptable treated levels, experience has shown that it is more difficult to reduce a "hydrocarbon" type odor of 6 threshold units than an algae-type odor of 15 units. It is therefore felt that a maximum limit on hydrocarbon odors be 6, and the average daily odor be less than 4 units.

CHAPTER 4

WASTE SOURCES

General

Green Bay and the streams tributary to it receive an estimated waste load of 500,000 pounds of 5-day 20°C biochemical oxygen demand (BOD_5) per day. Approximately 440,000 pounds of BOD_5 are from industry with separate discharges. The majority of this waste load is discharged into Green Bay from the Fox River. Significant waste loads are also discharged at the mouth of the Menominee, Oconto, Peshtigo, and Escanaba rivers.

The following paragraphs summarize the major waste sources in the Green Bay Area. The consequences of these discharges are described in Chapter 6.

Municipal Wastes

Approximately 454,000 people, served by 75 municipal sewage treatment facilities, discharged some 51,000 pounds of BOD_5 per day to the streams tributary to Green Bay. This is discharged as treated sewage from an untreated load of nearly 126,600 pounds of BOD_5 per day. This represents an overall reduction of 60%. Of the 75 municipal sewage treatment plants in the Basin eight are located along the Lower Fox River between Neenah-Menasha and the Bay. These eight plants discharge 30,200 pounds of BOD_5 per day or 60% of the total for the Basin.

Of the 75 treatment plants in the Basin, 54 plants provide secondary treatment. A municipal waste inventory of major communities is given in Table 4-1.

By 1980 the total waste load treated by municipal plants is projected to reach 190,000 pounds of BOD_5 per day. This assumes that by 1980 the total municipal population will be served by sewage treatment plants. Of this 190,000 pounds of BOD_5 per day 100,000 pounds will come from domestic sources while 90,000 will come from industries connected to public sewers. With a 90% treatment efficiency in terms of BOD_5 reduction the discharged load should be 19,000 pounds per day, or only about one-third the present municipal discharge. By the year 2020 the total waste load treated by municipal plants is projected to reach 370,000 pounds of BOD_5 per day, of which 230,000 will come from domestic sources while 140,000 will come from connected industry. With a 95% treatment efficiency attained by 2020, the discharged BOD_5 load would remain about 19,000 pounds per day.

TABLE 4-1 (14)

MUNICIPAL WASTE INVENTORY OF MAJOR COMMUNITIES GREEN BAY AREA, MICHIGAN AND WISCONSIN

Community	Receiving Stream	Miles Above Mouth	Treatment	Population Connected	Raw PE	Discharged PE
		Green Bay Perimeter				
Oconto	Oconto River	1.30	Secondary	4,700	10,300	1,360
Peshtigo	Peshtigo River	11.70	"	2,800	2,800	933
Marinette	Menominee River	1.60	Primary	13,000	15,000	10,000
Menominee	Menominee River	1.60	"	11,280	3,610	2,130
Escanaba	Portage Creek	1.20	Secondary	15,390	11,750	2,580
Gladstone	Little Bay de Noc	0	Primary	5,260	5,200	4,100
		Lower Fox River				
Green Bay	Fox River	0.30	Secondary	88,280	190,000	62,000
De Pere	" "	6.80	"	10,000	13,500	6,380
Appleton	" "	29.80	"	47,000	110,450	70,030
Little Chute	" "	25.30	"	5,100	5,100	1,000
Kimberly	" "	27.10	"	5,400	5,400	540
Kaukauna	" "	23.60	"	10,100	9,600	4,800
Neenah & Menasha	Little Lake Buttes Des Morts	37.60	Primary	32,705	50,000	36,000

TABLE 4-1 (14) (Cont'd)

MUNICIPAL WASTE INVENTORY OF MAJOR COMMUNITIES
GREEN BAY AREA, MICHIGAN AND WISCONSIN

Community	Receiving Stream	Miles Above Mouth	Treatment	Population Connected	Raw PE*	Discharged PE
		Upper Fox River				
Fond du Lac	Lake Winnebago	74.30	Secondary	33,000	54,000	11,000
Oshkosh	Fox River	57.40	"	50,685	60,000	31,200
Ripon	Silver Creek	120.70	"	6,765	8,000	200
Berlin	Fox River	87.90	"	4,830	14,580	2,412
Portage	" "	161.40	"	7,800	13,000	1,500
		Wolf River				
Waupaca	Waupaca River	112.80	Primary	4,000	4,840	3,630
New London	Wolf River	114.00	Secondary	5,300	15,400	5,460
Clintonville	Pigeon River	150.80	"	4,800	6,000	1,320
Shawano	Wolf River	184.30	"	6,300	15,000	2,600
		Mencminee River				
Iron Mountain-Kingsford	Mencminee River	95.40	Primary	14,370	9.400	5,530

* P.E. = 1/6 pound per-day BOD_5

Industrial Wastes

By far the largest source of waste in the Green Bay Area is industry with separate discharges (not connected to municipal plants). At present, industries are discharging some 440,000 pounds of BOD_5 per day. The waste flow from these industries is more than 160 mgd.

Almost the entire separately discharged waste load in the Green Bay Basin is being discharged by the pulp and paper mills in the Area. All other industrial sources(of greater than 100 pounds of BOD_5 per day) in the Area amount to only 2,000 pounds of BOD_5 per day.

An industrial waste inventory is presented in Table 4-2. Following the National and area trends, it is assumed that industrial growth will continue in the Green Bay Area. It is also expected that industrial waste treatment will greatly improve. The net result should be a significant decrease in the waste load discharged to the streams.

By 1980 industries with separate discharges are expected to have an untreated BOD_5 waste load of 1,140,000 pounds per day with a flow of 250 mgd. With the recommended 90% treatment in effect, the discharged waste load should be about 114,000 pounds of BOD_5 per day or less than one-third the present discharge from industry. By the year 2020 untreated industrial waste is projected to be approximately 2,000,000 pounds of BOD_5 per day at a flow of 410 mgd. With an anticipated 95% treatment in effect, the discharge load would be 100,000 pounds per day of BOD_5 or less than one-fourth the present industrial discharge to the streams.

It is anticipated most of the future industrial growth will take place along the Lower Fox River Areas. This concentration of industry along 39 miles of stream serves to magnify the need for extensive waste treatment facilities.

Combined Sewers

It has been estimated that a quantity, equivalent to 3 to 5 percent of all raw waste-water flow in combined sewer systems, is annually discharged to streams by overflows.(16) It is also known that a far greater percentage of the solids are discharged to streams from overflows. This is due to the fact that the sludge deposited in the sewers is flushed out by the storm flow.

Of the 75 communities with public sewer systems in the Area about 50 have separate sewer systems. However, because most of the larger communities have combined systems, about 70 percent of the population is served by combined systems.

TABLE 4-2 (15)

INDUSTRIAL WASTE INVENTORY (MAJOR INDUSTRIES)

Company Name	Location	Miles Above Mouth	Effluent MGD	BOD_5 lb/day	Susp. Solids lb/day	Treatment Received
			FOX RIVER			
Green Bay Packaging	Green Bay	0.4	2.10	33,300	5,340	Screens, saveалls & roadbinder
Charmin Paper Prod.	" "	0.7	14.53	45,920	17,880	Saveалls, yeast fermentation & evaporation
Marathon Paper	" "	0.8	21.33	46,920	15,120	Lagoon, Evaporation & roadbinder
Fort Howard Paper	" "	3.5	13.425	28,440	30,780	Saveалls & lagoons
U. S. Paper Mills Corp.	De Pere	7.0	-	-	-	-----
Nicolet Paper	" "	7.3	1.49	200	660	Saveалls
Charmin-Little Rapids	Little Rapids	13.0	0.03	228	198	
Thilmany Pulp & Paper	Kaukauna	23.6	23.63	33,080	19,380	Saveалls & lagoons
Combined Locks Paper	Combined Locks	25.8	2.98	4,200	12,880	Primary & saveалls
Kimberly Clark	Kimberly	27.2	12.69	52,740	39,440	Lagoon, roadbinder, saveалls
Consolidated Paper	Appleton	30.7	7.96	33,620	15,240	Evaporation & drying

TABLE 4-2 (15) (Cont'd)

INDUSTRIAL WASTE INVENTORY (MAJOR INDUSTRIES)

Company Name	Location	Miles Above Mouth	Effluent MGD	BOD_5 lb/day	Susp. Solids lb/day	Treatment Received
Oconto River						
Scott Paper Co.	Oconto Falls	22.9	11.3	38,000	7,500	Savealls, lagoon roadbinder
Peshtigo River						
Badger Paper Co.	Peshtigo	10.4	5.5	22,900	4,400	Saveall, roadbinder pending irrigation
Menominee River						
Kimberly-Clark	Niagara	85.1	10.1	17,360	-	Settling tanks
Scott Paper Co.	Marinette	2.9	7.3	52,900	-	Savealls & roadbinder
Scott Paper Co.	Menominee	-	1.0	910	-	Vibrator Screens Savealls
Marathon Corp.	Mencminee	-	1.6	4,410	-	Savealls
Escanaba						
Mead Corp.	Escanaba	-	6.8	11,150	12,500	

TABLE 4-2(15) (Cont'd)

INDUSTRIAL WASTE INVENTORY (MAJOR INDUSTRIES)

Company Name	Location	Miles Above Mouth	Effluent MGD	BOD_5 lb/day	Susp. Solids lb/day	Treatment Received
		FOX RIVER (con't.)				
Riverside Paper	Appleton	31.1	1.89	1,940	5,200	Savealls
Fox River	"	31.6	-	-	-	-
Whiting Paper	Menasha	37.1	0.15	128	374	Savealls
Marathon Paper	"	37.3	-	-	-	-
John Strange Paper	"	37.4	1.74	1,680	2,860	Savealls & Metropolitan sewers
Gilbert Paper	"	37.5	1.11	1,040	2,400	Savealls & Metropolitan sewers
Kimberly Clark	Neenah	37.8	5.71	2,400	6,220	Savealls & Metropolitan sewers
Bergstrom Paper	"	38.3	1.10	3,680	12,460	Primary
Kimberly Clark (Badger-Globe)	"	38.4	1.07	340	740	Some waste to metropolitan sewers
Kimberly Clark (Neenah Div.)	"	38.5	0.83	588	1,450	Savealls
Chicago Pickle	Redgranite	-	0.03	300	-	Ridge & Furrow irrigation

Table 4-3 below lists the major communities in the Green Bay Area and the type of sewer system they have.

TABLE 4-3

Major Community Sewer Systems

Community	Type of System
Green Bay	Combined
De Pere	Combined
Appleton	Separate-Combined
Little Chute	Combined
Kimberly	Separate
Kaukauna	Combined
Neenah-Menasha	Separate-Combined
Fond du Lac	Separate
Oshkosh	Separate-Combined
Oconto	Combined
Peshtigo	Combined
Marinette	Combined
Menominee	Separate-Combined
Iron Mountain	Combined
Escanaba	Separate
Gladstone	Combined

Agriculture and Land Runoff

Pesticides

Pesticides used in the Green Bay Area include insecticides, fungicides and herbicides. In applying the pesticides, particularly in large-scale aerial spraying, some of the material goes directly into the water. Algicides and aquatic weed control chemicals are directly applied to the water but, with proper precaution, bad effects can be minimized. Of the materials applied on land by spraying, dusting or as granular formulations much of the pesticide gets onto or into the soil. Although much of the material reaching the ground is lost through chemical reactions during the first few hours after application, it is the persistent pesticide that reaches the soil, or goes directly into the water, that is of concern in water quality.

The greatest amount of the pesticides used in the Area are applied on fruits and vegetables. There are two areas of extensive applications of pesticides, one located in the potato producing area in Langlade County and the other in the cherry orchard region of the Door Peninsula.

Table 4-4 shows the approximate amounts used in the area. For the two areas mentioned above, DDT accounts for the largest amount.

Because little is known concerning the long term effects of pesticides, further evaluation of the problem in the Green Bay Area should be incorporated into the program for the enhancement and protection of the water quality of Green Bay.

Fertilizers

In certain areas of the Green Bay Area the soil is only moderately productive and chemical fertilizers are used for high crop yields. Approximately 85 percent of these commercial fertilizers are applied in the spring and the remaining 15 percent are applied in the fall. Improper application, particularly in the spring, can result in the excessive loss of fertilizers into the streams. Feedlots and barnyards are also big contributors of nutrient wastes. The liquid part of the manure contains on the average, 45 percent nitrogen and 65 percent potash. Fertilizer use estimates show that approximately 5,400 tons per year of nitrogen and 13,000 tons per year of phosphate have recently been used in the Area.

A substantial amount of the phosphate found in the Lake Michigan tributaries originate as runoff from rural lands. Its subsequent effect, overfertilization of the Great Lakes requires that greater consideration be given to proper land use practices. Due to the importance of phosphates as related to Green Bay water quality a separate section dealing with sources of phosphate appears later in this Chapter. More quantitative material is presented in that section.

Summary

A sound land use management program designed to minimize erosion which results in the loss of soil, fertilizers and pesticides to streams is essential to the enhancement and protection of the quality of waters in the Area.

Federal Installations

The Federally-owned or Federally-leased installations listed below discharge waterborne wastes in the Green Bay, Wisconsin Area. Installations that discharge to municipally-operated sewerage systems have not been listed since the Federal Government does not control the treatment provided.

TABLE 4-4

INSECTICIDES USED IN THE MAJOR COUNTIES OF THE GREEN BAY AREA-WISCONSIN(17)

Commercial Fruit and Vegetable Production

Counties	Approx. Pounds Used-1962
Florence and Forest	600
Langlade	140,000
Oconto	9.800
Shawano	550
Waupaca	21,400
Outagamie	13,800
Brown	19,100
Door	185,300
Waushara	62,500
Winnebago	7,000
Marquette	41,200
Fond du Lac	5,400
Total	506,650

Locks and Dams on the Lower Fox River

There are sixteen locks and nine dams on the Lower Fox River operated by the U. S. Army Corps of Engineers, Chicago District. Normal operations run from May to November, and only pleasure craft use the River during this time. The locks are usually attended by one man at each location for eight hours a day, except for the Menasha and De Pere Locks which are attended sixteen hours a day. The residences at the locks are typical one-family dwellings and are used on a year-round basis. A list of the locks and dams and the facilities at each is shown in Table 4-5.

TABLE 4-5

Sanitary Facilities
Locks and Dams - Lower Fox River

Site	Buildings	Wastes Discharged
Appleton L & D #1	1 Residence	200 gallons per day(gpd) to a 500-gal. septic tank and tile drain field
Appleton L & D #3	Lock Tool House	1 privy - seldom used
Appleton L & D #4	Lock Tool House	1 privy - seldom used
Cedar Lock & Dam	1 Residence and Lock Tool House	200 gpd to 500-gal. septic tank & drain tile system
Kaukauna L & D #1	Residence and Warehouse	300 gpd to septic tank system
Kaukauna Lock #2	Residence	500 gpd to septic tank system
Kaukauna Lock #3	Lock Tool House	1 privy - seldom used
Kaukauna Lock #4	Lock Tool House	1 privy - seldom used
Rapid Croche Lock and Dam	1 Residence	200 gpd to 500-gal.septic tank & tile drain field
Little Kaukauna Lock & Dam	1 Residence	200 gpd to 500-gal.septic tank & tile drain field
De Pere Lock & Dam	Residence	400 gpd to 500-gal.septic tank & tile drain field

Green Bay Harbor Light Station

The U. S. Coast Guard Light Station in Green Bay is manned by 3 men for 24 hours a day between April 15 and December 15. The sanitary wastes generated at the Station amount to about 150 gpd and are discharged to Green Bay with no treatment. The Coast Guard is presently negotiating for the purchase of an experimental extended aeration package sewage treatment plant for use at installations of this nature.

Sherwood Point Light Station

This U. S. Coast Guard Light Station is located on Green Bay, along Sherwood Avenue, Sturgeon Bay, Wisconsin. All sanitary wastes generated at this facility (280 gpd) are discharged to a septic tank - drain field system.

Sturgeon Bay Canal Life Boat Station

This facility, located in Sturgeon Bay, Wisconsin is served by a septic tank and drain field system. Approximately 1,300 gpd of sanitary wastes are discharged to the system.

Plum Island Lifeboat Station

The U. S. Coast Guard Plum Island Lifeboat Station is located in the Porte Des Morts Strait, Door County, Wisconsin. During the navigation season approximately 900 gpd of sanitary wastes are discharged to a septic tank - tile drain field system.

Ships and Boats

The vessels plying the waters of Green Bay represent a potential source of pollution of the Bay. The possible sources of pollution include cargo spillage, dunnage, ballast and bilge waters, fuel spills, garbage and sanitary wastes. Uncontrolled discharge of these wastes can result in serious pollution problems for beaches, shore property, recreational waters, fish and aquatic life, and municipal and industrial water supplies.

While all new vessels built since 1952 specifically for use on the Great Lakes have been equipped with waste treatment facilities, ocean-going ships generally have no provision for waste treatment. The majority of these ocean-going vessels are designed to discharge sanitary wastes from multiple outlets making onboard waste collection and treatment an expensive and complex installation.

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Vessel waste discharges may endanger the health of persons using Green Bay for body-contact sports. It has been reported that pollution from recreational boats has necessitated closing of at least one beach on the Door County Peninsula.(18)

The U. S. Public Health Service has established regulations governing vessel waste discharges in the Great Lakes based upon their legal responsibility for the interstate control of communicable diseases. Restricted areas have been established in which the discharge of sewage, ballast or bilge water, from vessels is prohibited. Restricted areas include the water within a three mile radius of domestic water intakes. These restrictions apply to the waters within a three mile radius of the water intakes for the major communities of Escanaba, Menominee, Gladstone and Nahma, Michigan and Marinette, Wisconsin.(19)

Dredging

Maintenance dredging of Green Bay Harbor is done by the Corps of Engineers to maintain authorized navigation depths. Dredged materials are usually disposed of in the deep (over 50 feet) waters of Green Bay. Such disposal of any organic material which may be dredged produces a polluted zone in the dumping area.

Legislation passed in 1962 authorized an increase in project depths for Green Bay Harbor. The Corps plans to start work on deepening of the Harbor during this (1966) construction season. The proposed work has been coordinated with the appropriate State and Federal agencies, with the result that all dredgings considered to contain pollutional material will be deposited either on shore or within a diked area to be constructed by the Corps in Green Bay about two miles north of the mouth of the Fox River. The capacity of the diked disposal area will also accommodate the maintenance dredging for a number of years into the future.

Phosphates

Transport to Streams and Lakes from Rural Lands

In order to assess the relative amounts of phosphate and other substances transported to streams by rural runoff in the Lake Michigan Watershed during 1963-1964, the GLIRB Project conducted a sampling study of eight streams draining small rural watersheds.(20)

The amount of total soluble phosphate reaching streams from land runoff, in the Green Bay Area, as estimated from samples taken on the eight pilot watersheds, is about 1,167,000 pounds annually or about 0.1 pounds per acre of watershed.

Municipal Sources

Domestic sewage is relatively rich in phosphorus compounds. Most of this phosphorus comes from human excreta and synthetic detergents. The amount of phosphorus released by human metabolic processes is a function of protein intake and for the average person in the United States, this release is considered to be about 1.5 grams per day.(21) Synthetic detergent formulations contain large amounts of phosphates. It is estimated that 2.5 grams per day per capita of phosphorus are discharged to sewer systems as a result of the use of synthetic detergents.

When the above per capita figures for phosphorus from human excreta and detergents are expanded to cover the entire sewered population of the Green Bay Area the quantity becomes quite large as shown below. The GLIRB Project municipal waste inventory shows that 451,000 people are served by sewer systems in the Area.

From a study of five sewage treatment plants in Illinois and Indiana it was found that the average phosphate removal was 38 percent. Using the above figures on population and the per capita phosphorus discharged, along with the average percent removal, it is estimated that a total of approximately 2,770,000 pounds of soluble phosphate are discharged to the waters of the area from humans and detergents each year. Of this total, 867,000 pounds are discharged directly to Green Bay while 1,903,000 pounds are discharged to its tributaries.

Tributary Mouth Sampling

In addition to the land runoff sampling from the eight small subbasins discussed above, sampling stations were established at the mouths of major tributaries to Green Bay. These stations were also sampled continuously for one year during the same period in which the land runoff stations were sampled.

Sampling at the mouths of the tributaries made it possible to measure the total phosphate load reaching Green Bay. When the discharge from the rivers was determined a summary showed a total of approximately 4,270,000 pounds of soluble PO_4 being discharged to the Bay annually.

Summary

The amount of phosphate reaching streams from land runoff, in the Green Bay Area, estimated from samples taken on 8 pilot watersheds is about 1,167,000 pounds annually.

An estimated 2.7 million pounds of phosphate are discharged annually in municipal waste effluents in the Area. It is estimated that 867,000 pounds of phosphate are discharged to Green Bay annually.

Based on sampling of major Green Bay tributaries at the mouth, about 4,270,000 pounds of total soluble phosphate goes into the Bay annually from tributaries. Thus, the present annual phosphate input to Green Bay is around 5 million pounds. Water quality problems which result from this nutrient input are discussed in Chapter 6.

CHAPTER 5

LAKE CURRENTS

Background

Intensive studies of currents and temperature changes were made by the GLIRB Project in and adjacent to Green Bay as part of the study program for the Great Lakes. Lake current studies were limited to the main passage between Green Bay and Lake Michigan. Three separate temperature studies were made in Green Bay during 1962 and 1963. Automatic recording current meters and thermographs were used in the studies.

In addition to the present effort, there have been several other studies. R. Johnson has published three reports on the water quality conditions in the Escanaba region in 1960, 1962, and 1963.(22,23,24) In 1964, J. Saylor reported on current studies of the U. S. Lake Survey in the Sturgeon Bay Canal.(25) In 1965, Dr. C. Mortimer reported on a power spectra analysis of water level data obtained at the City of Green Bay.(26)

General Patterns

Winds, seiches, and tidal effects are the primary factors which influence the flow of water in Green Bay. Wind is the principal energy source for putting the water in motion. The movement of water is modified by bottom topography. Generally, water movement tends to parallel the shore as the water depth decreases.

Density plays a role in the movement of materials discharged into the Bay. A pollutant discharged into the Bay can rise, sink or come to rest on the thermocline depending on its initial density with respect to the density of the water.

The free oscillation of a water mass in its basin is known as a seiche. Although differences in water elevation in Green Bay are not exceptionally large, seiches and tides have been recorded in Green Bay since the time of the earliest French explorers. Seiches and tides produce rhythmic changes in elevation but contribute little to the transport or mixing of water.

Existing currents, or the absence of currents, also affect the mixing of a pollutant. If a pollutant is discharged into the Bay during near calm periods, it will build up into a stationary mass. If the pollutants are discharged into an existing current, it will be diluted by the moving water. The initial dilution depends on the rate of discharge of the pollutant and the speed of the current. Mixing studies conducted by the GLIRB Project in the Great Lakes show that small dilution ratios of Bay water to pollutants can produce severe local problems depending on the amount of pollutant discharged.

The most important types of motion are turbulent mixing and transport. Mixing refers to the rate of dilution of a pollutant. Transport is the net movement of a water mass from one area to another.

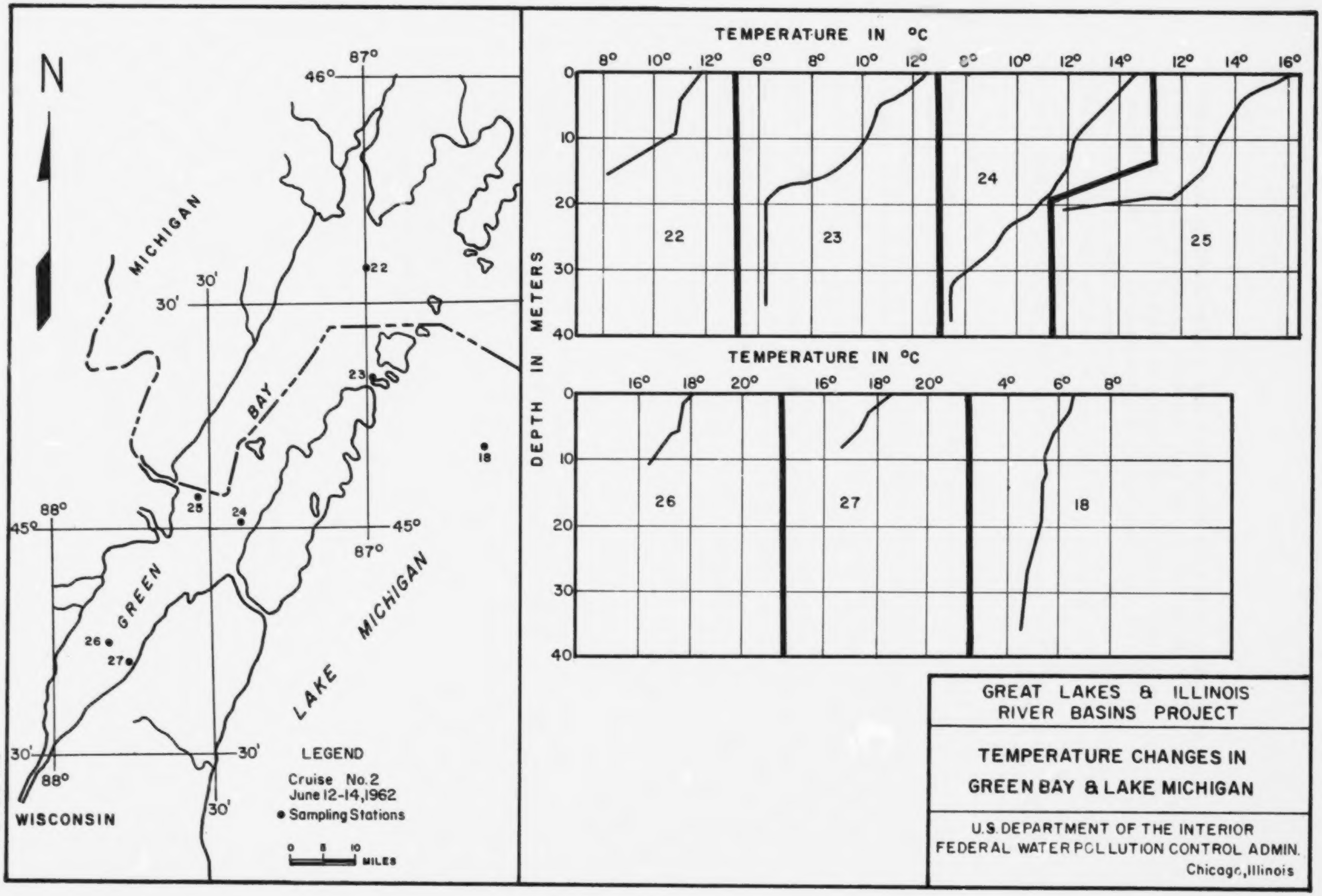
The principal tributary inflow into Green Bay is the Fox River. The Fox and other rivers, such as the Peshtigo, Oconto, Menominee, and Escanaba contribute, on an annual average, from 10,000 to 11,000 cubic feet per second to the Bay. This inflow represents a turnover period of about 15 years in the Bay. In October 1963, the period of the GLIRB Project current studies, the flow averaged about 4000 to 5000 cfs.

The discharge of the several streams and rivers into Green Bay produces a net flow of water into Lake Michigan. The net surface flow is to the northeast with a return compensating flow in the deeper layers.

Green Bay becomes thermally stratified weeks before the adjacent deeper water of Lake Michigan. The shallow southern end of the Bay is nearly 13°F warmer than the deeper north end in June, and more than 22°F warmer than the deeper lake water. Records in June 1962 and May and June 1963 show that the thermal stratification in Green Bay is separate from the main portion of the Lake.

Figure 5-1 shows the temperature differences between various parts of Green Bay and the Lake proper. Major influxes of Lake water would certainly affect the thermal structure of the Bay and retard the rapid heating which occurs if the Lake controlled the Bay circulation.

The wind patterns for the late summer and early fall of 1963, which included the period of the current studies, show that the highest percentage of the net flow was from the directions west through south-southwest. For the late fall and winter months of 1963-1964 the highest percentage of the net flow, or prevailing wind was from the directions west through northwest. April of 1964 is the only month that showed a prevailing wind from Lake Michigan, an east-southeast wind. For May-August of 1964 the prevailing wind was south through southwest.



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

TEMPERATURE CHANGES IN
GREEN BAY & LAKE MICHIGAN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Chicago, Illinois

FIGURE 5-1

Although the water in Green Bay has a circulation independent of Lake Michigan there are daily and seasonal interchanges. In late fall and spring, winds from Lake Michigan undoubtedly bring in large volumes of water from the Lake which are trapped in the Bay. These influxes probably do not extend into the Bay more than a few miles, but most of the water is trapped and does not return to the Lake. This type of influx is less important than the daily input from the Lake through the many passages between the Bay and the Lake, as was observed from current meter measurements.

Current data in Big Rock Passage shows a constant reversal of flow every 12 hours. The reversal is due to seiche and tidal activity in the Bay and Lake. The tidal influence in Green Bay has been reported by Johnson, Saylor and Mortimer in their earlier studies. Mortimer suggests that one of the Green Bay periods is driven into resonance by the nine-hour Lake period. The principal mode for Green Bay is approximately 11.2 hours. Although the current reverses every 12 hours the upper 60 feet show a net outflow and the lower depths show a net inflow into the Bay. The net outflow is far greater than the inflow as would be expected. The net inflow from the Lake to the Bay in the lower layers is slightly greater than the combined flow of all streams and rivers entering the Bay. The inflow acts in the same manner as a major river entering the Bay. Although the circulation of the Bay is completely independent of the Lake, the water quality of the Bay will reflect the large inflow from the Lake.

Summary

On the basis of temperature and wind effects Green Bay appears to be an independent Lake separate from Lake Michigan. Local interaction between the Bay and the Lake produce a changing current pattern every 12 hours. The seiche or wind coupling with the Lake, plus inflow from Lake Michigan below the 60 feet depth and occasional northeast storms, act to dilute portions of the northern basin of the Bay with inflows from Lake Michigan. The southern reaches of the Bay, south of the Sturgeon Bay Canal, are probably not affected by any inflows from the Lake.

CHAPTER 6

PRESENT WATER QUALITY AND PROBLEMS

General

The information and interpretations presented in this discussion are based on data collected by the GLIRB Project during its water quality studies of the Lake Michigan Basin (1962-1964). The GLIRB Project studies have been supplemented by data obtained from the States of Wisconsin and Michigan and regional and local agencies.

Summary

The chemical, biological and bacteriological data presented on the subsequent pages are the basis for the following conclusions with respect to water quality effects:

1. The water quality of parts of Green Bay may be considered as separate from Lake Michigan, because of the relatively minor mixing of its waters which results in a differing water quality from the main body of the Lake.

2. Areas of degraded water quality are generally confined to zones near the mouths of tributary streams, harbors, and population centers where treated and untreated waste discharges are prevalent.

3. The principal water quality problems of the degraded areas are due to high concentrations of ammonia, phosphate and phenol, and low dissolved oxygen concentrations resulting from organic wastes. The presence of tolerant benthic animals in large numbers, along with dense concentrations of plankton algae, and the presence of high concentrations of coliform bacteria also indicate degraded water quality conditions.

4. The region most degraded is at the southern tip of Green Bay adjacent to the mouth of the Fox River.

5. Other degraded zones appear at the mouths of the Oconto, Peshtigo, Menominee and Escanaba Rivers.

6. The Lower Fox River, tributary to Green Bay, is grossly polluted, contributing the bulk of the phosphate, ammonia, phenol and organic contaminants and having at times little or no dissolved oxygen for distances exceeding 20 miles.

7. The coliform levels in the Lower Fox River have been found to be as high as 600,000 per 100 ml. Other biological analyses confirm the gross pollution of this stream.

8. The Oconto River, between Oconto Falls and its mouth, is severely degraded by organic pollution.

9. The Peshtigo River below Peshtigo to its mouth is also severely degraded from organic pollution.

10. The Menominee River is degraded by organic pollution for 25 to 30 miles below Niagara, Wisconsin.

11. Other streams tributary to Green Bay show varying degrees of pollution as generally reflected in the quality of water near the tributary mouths.

Physical and Chemical Aspects

Green Bay

Table 6-1 presents a summary of the physical and chemical data collected by the GLIRB Project and Figure 6-1 indicates the approximate location of the sampling stations. The Bay was divided into the selected zones as shown in the figure to facilitate interpretation of the collected data. These zones, except for tributary mouths, harbors, and near-shore areas, represent areas of similar water quality.

Examination of Table 6-1 shows the following significant water quality variations:

1. It is apparent that there is a severe depletion of dissolved oxygen in Zone 1. Some oxygen depletion is evident near the mouth of the Peshtigo River, in Zone 3.

2. The concentration of phosphate in Zone 1 is far above the level of 0.03 mg/l considered critical for the stimulation of algal blooms. (22) Levels of phosphate in other zones also exceed the critical levels except for Zone 5.

3. Ammonia nitrogen levels are highest in Zone 1 but are consistently high throughout the other zones in Green Bay.

4. Nitrate nitrogen values are significantly low throughout the Bay.

5. Chloride, dissolved solids and sulfate are highest in Zone 1, showing the extent to which the Fox River outflow affects the water quality of the Bay, and the lack of mixing in this zone.

6. The high concentration of phenols found in Zone 1 is due to industrial waste discharges to the Fox River.

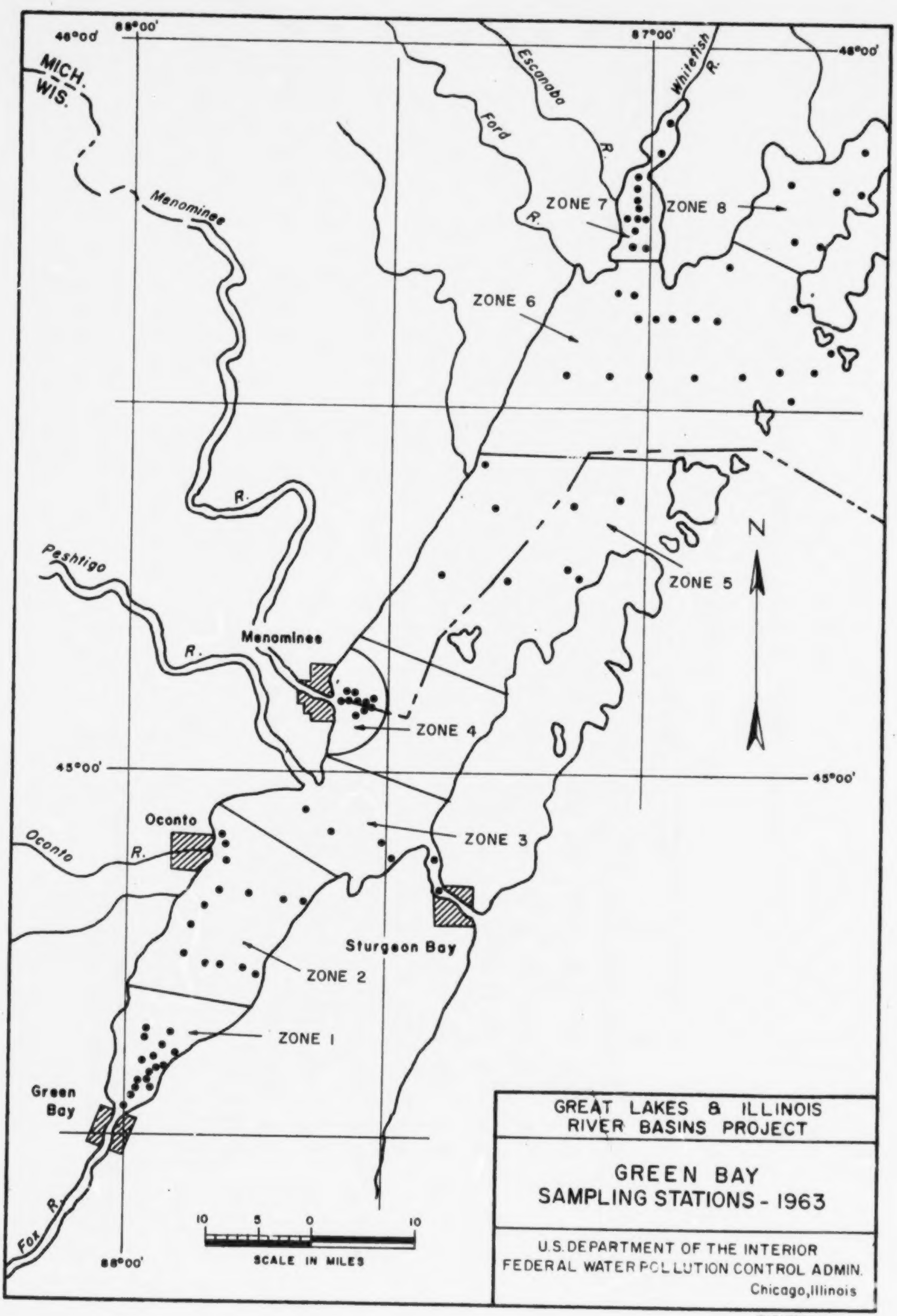
TABLE 6-1

CHEMICAL RESULTS BY ZONES IN GREEN BAY
JUNE 26 - JULY 17, 1963

Concentrations Expressed in mg/1

	D.O.			%	PO_4		NH_3-N		NO_3-N		SiO_2		Cl		Phenol*		Dissolved Solids		SO_4	
Zone	N.S.	Min.	Avg.	Sat.	N.S.	Avg.	N.S.	Avg.	N.S.	Avg.	N.S.	Avg.	N.S.	Avg.	N.S.	Avg.	N.S.	Avg.	N.S.	Avg.
1	7	0.0	4.5	52	19	0.20	17	0.46	3	0.01	19	1.7	11	13	3	21.0	10	233	11	22
2	17	7.3	8.3	93	21	0.06	21	0.13	17	0.02	19	1.5	17	7.9	4	3.0	14	188	17	19
3	12	5.1	8.2	88	10	0.07	13	0.18	9	0.04	9	1.5	11	6.7	9	3.5	6	181	9	19
4	20	7.2	9.2	92	20	0.03	19	0.17	21	0.06	20	2.0	14	6.6	7	0.4	10	178	14	19
5	27	9.3	10.4	101	3	0.01	27	0.12	27	0.10	25	2.1	24	6.5	1	2.5	-	-	24	17
6	33	9.8	10.8	108	29	0.05	30	0.13	29	0.10	28	2.4	24	6.6	2	2.1	14	175	25	20
7	47	7.7	9.9	104	31	0.07	32	0.17	31	0.08	31	2.3	30	5.9	10	3.2	21	173	31	19
8	18	9.2	10.0	103	12	0.09	11	0.13	12	0.05	12	2.4	12	6.3	3	0.0	3	165	12	19
Total Number of Samples																				
	181				145		170		149		163		143		39		83		143	

* Concentrations expressed in micrograms/liter.
N.S. Denotes number of samples.


46°00'
88°00'
87°00'
46°00'
MICH.
WIS.
Menominee
Escanaba
Ford
Whitefish
R.
R.
R.
ZONE 7
ZONE 8
ZONE 6
R.
N
ZONE 5
Peshtigo
R.
Menominee
ZONE 4
45°00'
45°00'
Oconto
Oconto
R.
ZONE 3
Sturgeon Bay
ZONE 2
ZONE 1
Green Bay
Fox R.
88°00'
10
5
0
10
SCALE IN MILES

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

GREEN BAY
SAMPLING STATIONS - 1963

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Chicago, Illinois

FIGURE 6-1

A comparison of the above findings with the Water Quality Criteria presented in Table 3-6 indicates that several beneficial water uses are being jeopardized. To further emphasize the seriousness of the waste discharges into Green Bay the two significant nutrients, ammonia nitrogen and phosphate, are shown in Figures 6-2 and 6-3. These figures give the concentrations and approximate average daily loadings from the larger tributaries. The Fox River is the most important contributor, discharging 6,670 pounds of phosphate daily. The Menominee River is the next largest contributor with 1,930 pounds per day. The Fox River discharges 37,200 pounds of ammonia nitrogen per day or almost three times as much as the Oconto River the next highest contributor, at 9,840 pounds per day. Other sources of nutrient loadings have also been discussed in Chapter 4.

Green Bay Tributaries

Two programs of study were carried out by the GLIRB Project with respect fo water quality of the tributaries. The first consisted of weekly sampling of tributary mouths to determine average annual loadings discharged to Green Bay, as well as water quality variability. The second consisted of intensive studies of stretches of certain tributaries to determine the effect of organic wastes on stream oxygen resources.

The data obtained from the first study program are summarized in Tables 6-2 and 6-3. The phosphate and ammonia nitrogen data are also shown in Figures 6-2 and 6-3. From these data it is apparent that the Fox River is the principal contributor of nutrients to the Bay and its contribution is greater than the combined totals of all of the other streams. The presence of the toxic metals, copper, zinc, nickel, and lead in detectable amounts can be considered as a potential threat to water uses involving fish and aquatic life. The other constituents serve to differentiate the chemical water quality of the various streams. The composition of the dissolved matter found may reflect the effects of minerals leached from the ground, municipal or industrial waste discharges, or urban and rural runoff. Except for the nutrients previously cited, these inputs have relatively little influence on the chemical water quality of the Bay.

To show the effect of organic loadings on the oxygen resources of the Fox River, a typical profile of the dissolved oxygen and biochemical oxygen demand concentrations found during this study are shown in Figure 6-4. The high BOD levels carried by the Lower Fox result in the complete absence of dissolved oxygen for a stretch of eleven miles and levels of less than 2 mg/1 for over twenty miles. Fish and desirable aquatic life cannot survive under such degraded oxygen conditions and the stream is unsuitable for other uses. This is indicated in Tables 3-1 and 3-7. The odors and anaerobic gases released by this pollution makes the stream esthetically undesirable

TABLE 6-2

AVERAGE CHEMICAL RESULTS AND LOADINGS
GREEN BAY TRIBUTARIES
1963-1964

River		Total Soluble PO_4	NH_3-N	NO_3-N	Org-N	Total Dissolved Solids	Total Suspended Solids	SO_4	Cl	SiO_2	Ca
Fox[2]	a)	0.28	1.56	0.10	0.48	271	25	52	21	9.4	40
	b)	18	18	18	18	13	18	18	18	18	18
	c)	0.14-0.45	1.13-1.73	0.05-0.23	0.37-0.53	196-285	17-59	42-75	16-28	9.2-9.8	38-44
	d)	6670	37200								
Oconto[2]	a)	0.17	2.31	0.20	0.92	262	14	22	15	9.2	39
	b)	42	42	40	42	42	42	42	42	42	42
	c)	0.03-0.50	0.09-6.30	0.04-0.43	0.00-8.38	196-342	8-29	8.5-66	5.8-20	7.0-10	33-43
	d)	724	9840								
Peshtigo[2]	a)	0.08	0.14	0.15	0.45	281	15	24	11	9.8	33
	b)	42	38	37	38	44	44	44	44	44	44
	c)	0.01-0.23	0.06-0.30	0.02-0.50	0.20-1.11	132-1212	2-24	1.3-134	0.9-72	1.6-17	24-38
	d)	384	672								
Menominee[3]	a)	0.11	0.24	1.67	0.39	154	13	17	7.3	4.4	28
	b)	15	18	18	18	14	15	18	18	18	18
	c)	0.02-0.15	0.05-0.30	0.00-2.56	0.09-0.55	45-187	4-32	6.5-23	4.0-9.0	4.0-6.4	22-29
	d)	1930	4200								
Ford[2]	a)	0.04	0.12	0.40	0.45	203	7.1	20	2.7	7.0	40
	b)	25	45	45	45	24	20	45	45	45	45
	c)	0.00-0.22	0.02-0.35	0.01-1.50	0.13-0.84	141-303	4.0-8.0	7.4-43	2.0-4.5	6.0-8.8	27-50
	d)	73	218								
Escanaba[2]	a)	0.06	0.11	0.10	0.41	166	16	20	2.8	7.0	28
	b)	38	42	42	42	44	44	44	44	44	44
	c)	0.01-0.33	0.04-0.17	0.04-0.35	0.14-1.15	72-230	6-77	1.0-50	1.9-5.0	4.7-9.1	13-31
	d)	329	603								

TABLE 6-2 (Cont.)

River		Total Soluble PO_4	NH_3-N	NO_3-N	Org-N	Total Dissolved Solids	Total Suspended Solids	SO_4	Cl	SiO_2	Ca
Rapid[3]	a)	1.59	0.62	0.24	0.89	240	18	4.1	5.5	3.1	35
	b)	17	17	17	17	17	17	12	17	17	17
	c)	0.01-3.83	0.04-0.94	0.00-0.49	0.15-1.78	168-531	2-86	3.0-10	2.2-7.1	2.7-4.0	28-37
	d)	686	267								
White-fish[3]	a)	0.18	0.11	0.14	0.25	196	5	20	2.0	5.7	34
	b)	18	15	15	15	15	18	18	18	18	18
	c)	0.04-1.00	0.09-0.12	0.12-0.18	0.23-0.30	170-209	3-8	11-33	1.5-2.5	4.2-6.9	27-37
	d)	220	135								

a) = Average concentration (mg/l)
b) = Number of samples collected
c) = Range (mg/l)
d) = Loading (lbs/day)

[1] from composites prepared according to flow, except all toxic metals values represent a single composite.

[2] June 12, 1963 - May 6, 1964

[3] June 12, 1963 - October 24, 1963

TABLE 6-3
AVERAGE CHEMICAL RESULTS
GREEN BAY TRIBUTARIES
1963 - 1964

River		Mg	Na	K	ABS	Cu	Cd	Ni	Zn	Cr	Pb
Fox[2]	a)	14	14	3.8	-	0.09	*	0.02	*	*	0.04
	b)	18	18	18	0	18	18	18	18	18	18
	c)	9.8-21	10-16	2.9-4.3	-						
Oconto[2]	a)	14	3.8	1.8	0.10	0.01	*	0.03	0.03	*	0.05
	b)	42	42	42	42	42	42	42	42	42	42
	c)	9.3-16	2.6-4.4	1.2-3.9	0.01-0.14						
Peshtigo[2]	a)	12	2.5	1.3	0.12	0.15	*	0.03	0.04	*	0.05
	b)	44	44	44	44	44	44	44	44	44	44
	c)	8.5-32	1.3-4.6	0.8-4.1	0.00-1.60						
Menominee[3]	a)	11	2.7	1.2	0.09	-	-	-	-	-	-
	b)	18	18	18	18	-	-	-	-	-	-
	c)	9.0-12	1.6-3.1	0.9-1.4	0.08-0.10						
Ford[2]	a)	20	1.8	1.1	0.18	0.06	*	0.03	0.03	*	0.06
	b)	45	45	45	45	45	45	45	45	45	45
	c)	10-28	1.0-2.4	0.5-1.3	0.08-0.71						
Escanaba[2]	a)	9.0	2.9	1.1	0.21	0.09	*	0.03	0.03	*	0.07
	b)	44	44	44	44	44	44	44	44	44	44
	c)	4.2-11	1.4-3.9	0.7-1.5	0.08-0.60						
Rapid[3]	a)	12	1.8	1.5	0.14	-	-	-	-	-	-
	b)	17	17	17	17	-	-	-	-	-	-
	c)	8.0-14	0.7-2.4	0.4-2.2	0.09-0.17						
White-fish[3]	a)	14	3.4	0.7	0.10	-	-	-	-	-	-
	b)	18	18	18	18	-	-	-	-	-	-
	c)	9.7-15	2.4-4.5	0.5-0.9	0.08-0.16						

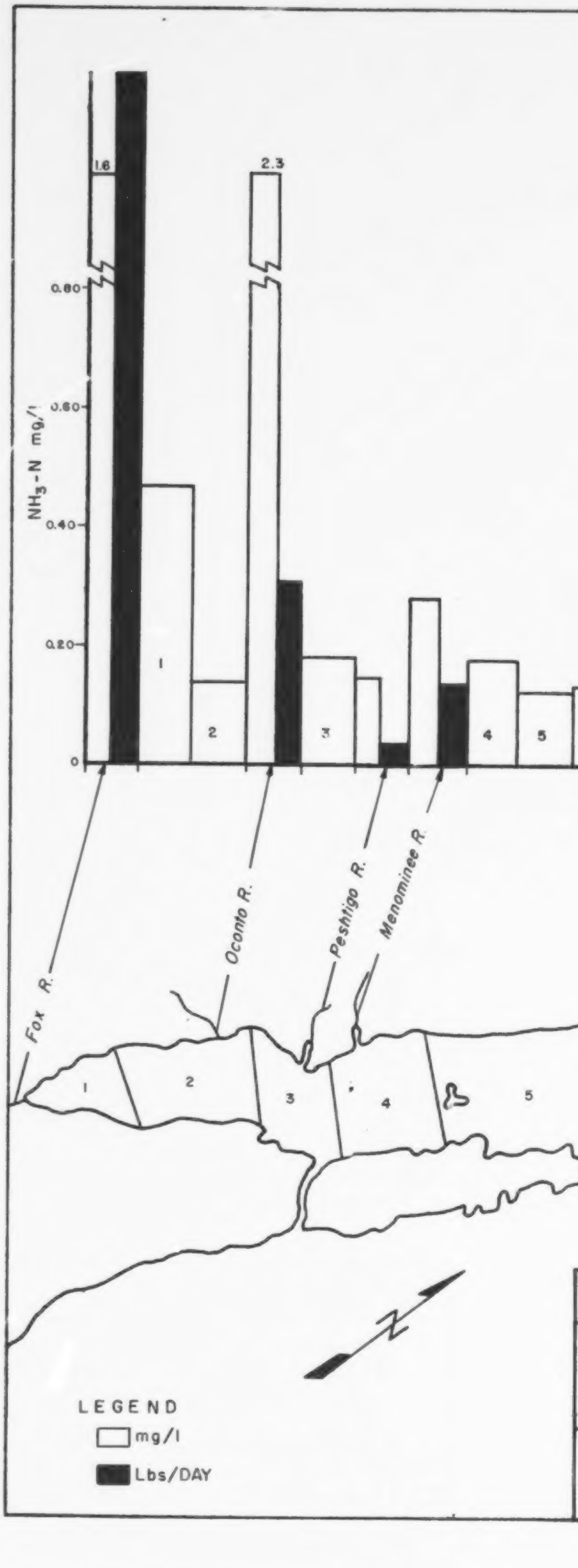
a) = Average Concentration (mg/1)
b) = Number of samples collected
c) = Range (mg/1)

*Not detected at sensitivity of test (0.01 mg/1)

[1] From composites prepared according to flow, except all toxic metals values represent a single composite.

[2] June 12, 1963- May 6, 1964

[3] June 12, 1963- October 24, 1963



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

GREEN BAY & TRIBUTARIES
AMMONIA NITROGEN
March, 1963 – April, 1964

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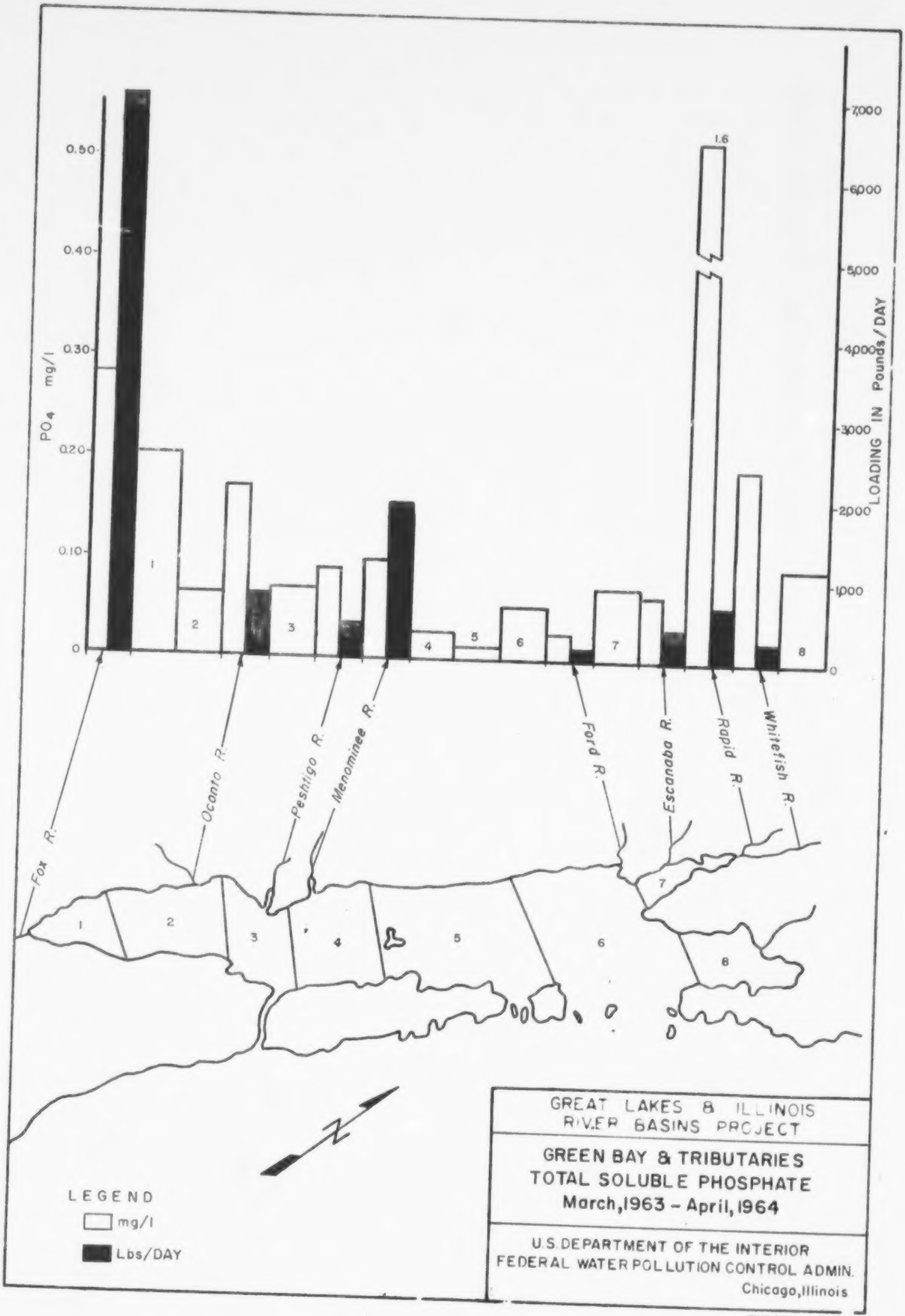
FIGURE 6-2



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

GREEN BAY & TRIBUTARIES
TOTAL SOLUBLE PHOSPHATE
March, 1963 – April, 1964

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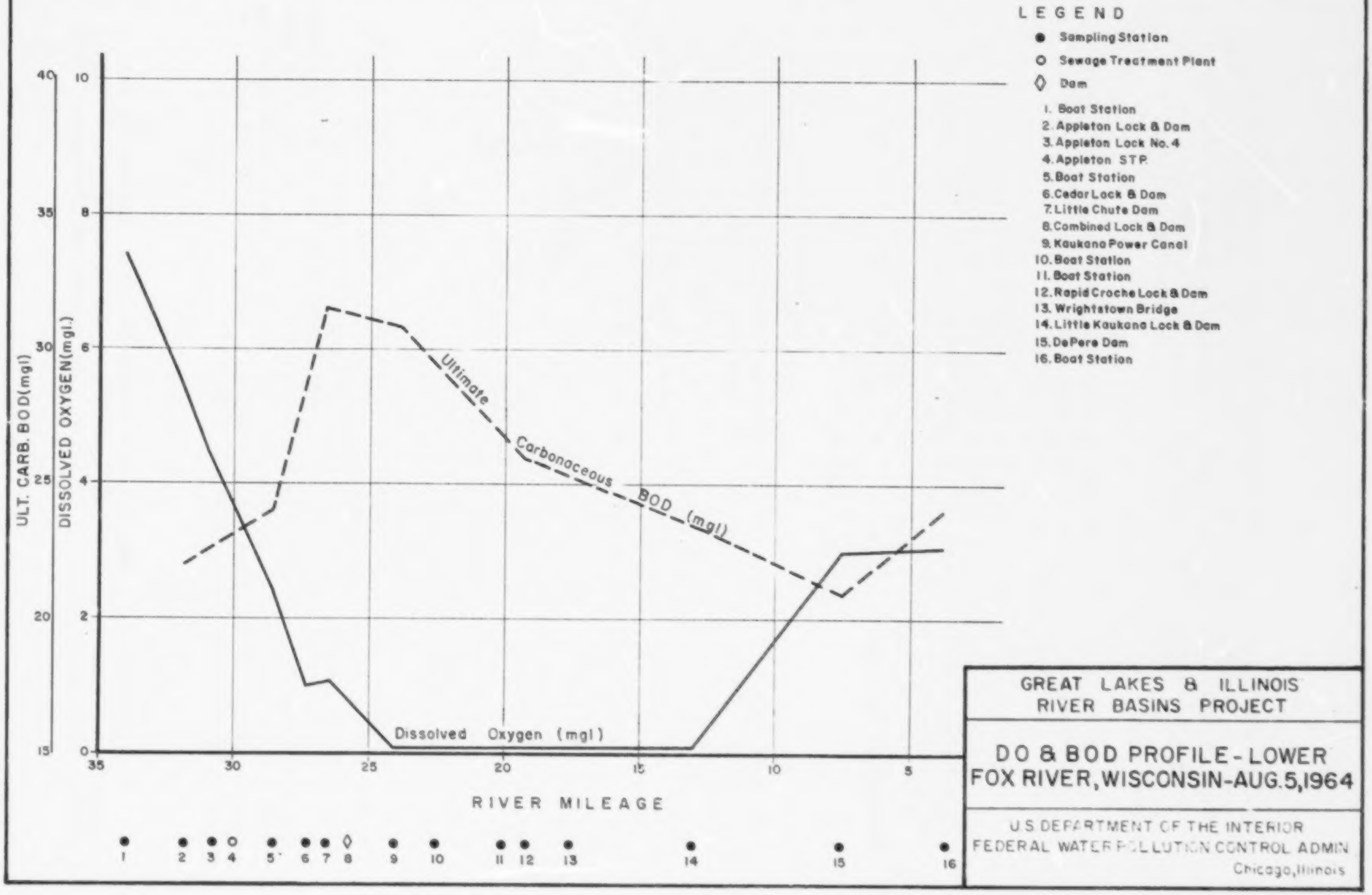
Chicago, Illinois

FIGURE 6-3



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

DO & BOD PROFILE - LOWER
FOX RIVER, WISCONSIN - AUG. 5, 1964

U.S. DEPARTMENT OF THE INTERIOR
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Chicago, Illinois

FIGURE 6-4

and very objectionable for recreational uses such as boating, water skiing, and similar aquatic sports. The organic loadings causing this highly polluted condition are known to originate primarily from the discharges of the many pulp and paper mills located along the Lower Fox River. The inventory of industrial waste discharges is given in Chapter 4.

The heavy organic loadings responsible for the polluted conditions of the Lower Fox River carry their effects into Green Bay in the zone near the River mouth, as discussed earlier.

The Oconto River, between the City of Oconto Falls and its mouth has been affected in a similar manner, by industrial wastes. Data collected by the State of Wisconsin indicate the highly anaerobic condition of this stream.

Biological Findings

General

The kinds and numbers of aquatic plants and animals inhabiting a particular body of water, and the stream or lake bottom beneath it, reflect the quality of water that has generally prevailed in the area for an extended period of time. Some plants and animals are capable, by virtue of physiological features or living habits, of withstanding polluted conditions. They multiply rapidly when competition with less tolerant forms is eliminated. Examples of pollution-tolerant animals are the sludgeworms, bloodworms, leeches, and pulmonate snails, that exist in the decaying organic sediment which builds up from the setteable organic solids present in most waste discharges. A benthic (bottom-dwelling) population consisting of many kinds of organisms with low numbers of each species is typical of unpolluted waters. The relative scarcities of pollution-sensitive organisms, usually scuds, and the concomitant abundance of pollution-tolerant forms, usually sludgeworms, are considered reasonable indicators of lake areas subjected to organic enrichment if all other conditions are favorable.

Plankton algae are microscopic, chlorophyll-bearing plants suspended in the water. The density of algae in the water is dependent upon several factors, including the concentration of nutrients. All other factors being favorable, the higher the concentration of nutrients, the greater will be the density of algal growth. To a degree, they also indicate the quality of the water in that the kinds and numbers of algae present depend on the chemical and physical composition of the water in which they originated and in which they live.

Green Bay

Deleterious effects of waste discharges from tributaries were evident in a number of areas of Green Bay. The bottom fauna consisted almost entirely of pollution-tolerant sludgeworms and bloodworms which thrive in the rich organic sediments. A depression of clean-water associated bottom animal populations, probably as a result of waste discharges from the Fox, Menominee, Oconto and Peshtigo Rivers was exhibited.

The Bay exhibited dense concentrations of plankton algae. Pigmented flagellates, blue-greens and greens predominated. These types are typical of waters subject to organic enrichment.

Southern Green Bay and Fox River Tributary Data

The type of bottom found at the southern tip of Green Bay was mostly organic sediment. This is a favorable habitat for the pollution-tolerant sludgeworms and bloodworms which were the predominant organisms. Total populations in 1962 and 1963 ranged from 5,000 to 15,000 organisms per square meter near the mouth of the Fox River and gradually decreased to about 500 organisms per square meter ten miles out into the Bay. See Figure 6-5. Some pollution-sensitive snails were found about five miles from the mouth of the Fox River, indicating a trend toward improved water quality.

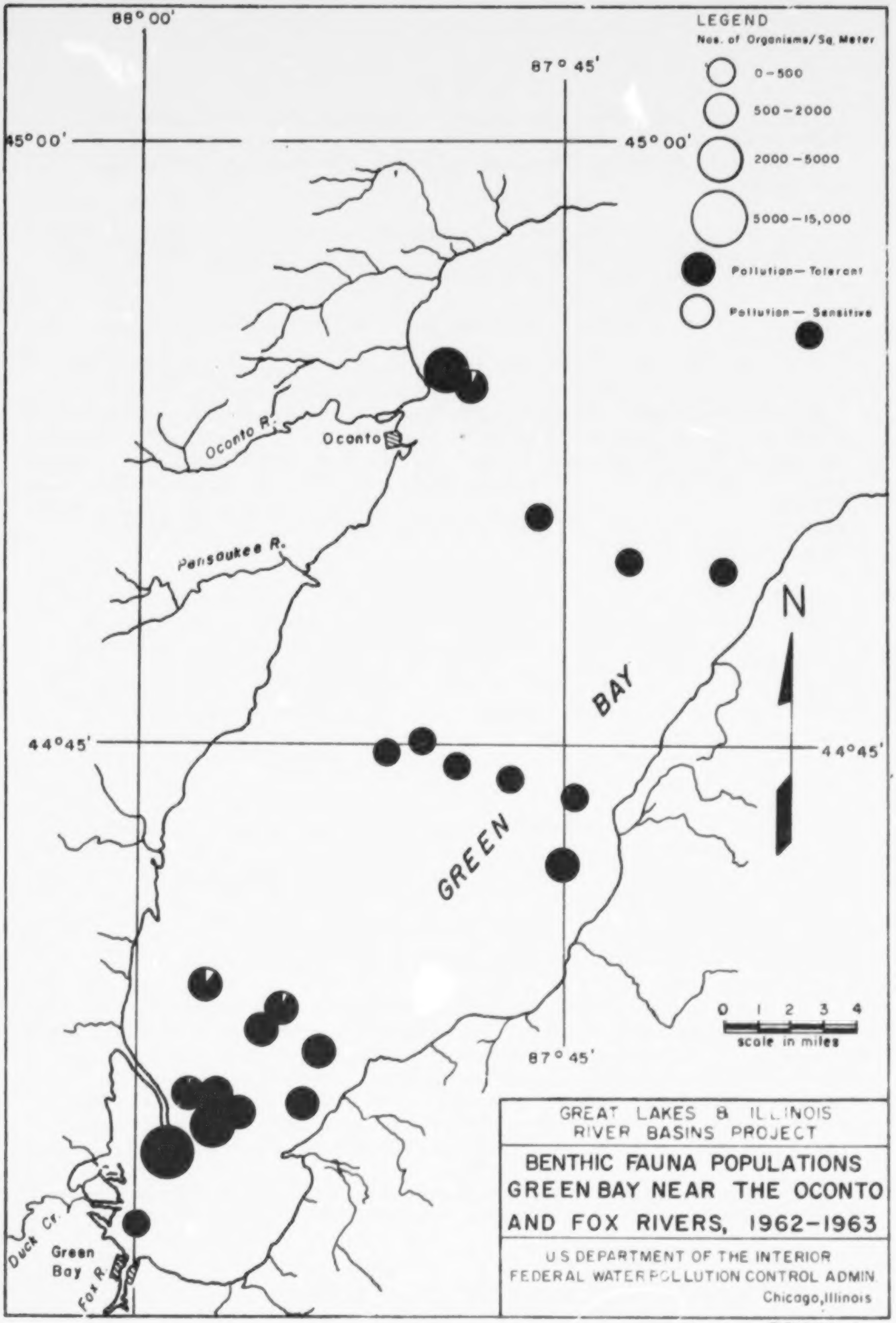
The highest phytoplankton populations, as in the case of the benthic fauna, occurred near the mouth of the Fox River as shown in Figure 6-6. In July 1963, total populations of 20,000 per milliliter were found. These numbers decreased to 5,000 to 10,000 about ten miles out into the Bay. The kinds of phytoplnakton in this area were mostly green flagellates, centric diatoms and green coccoids, common in enriched waters. Blue-green forms were also found in large numbers, from 700 to 1,500 per milliliter. They are generally considered pollution-tolerant.

Biological degradation was further indicated by a large phytoplankton bloom in southern Green Bay in July 1963. Counts were over 60,000 per milliliter. Large floating masses of Cladophora, a filamentous green algae, was found in southern Green Bay near the western shore.

Green Bay - Oconto River Tributary Area

Benthic populations ranged from 2,000 to 5,000 organisms per square meter near the mouth of the Oconto River in 1962 and 1963. See Figure 6-5. Five miles from the mouth, populations had decreased to about 500 bottom animals per square meter. The bottom deposits consisted mostly of organic sediment. The Oconto River area was predominated by bloodworms rather than sludgeworms and a few pollution-sensitive scuds existed less than two miles from its mouth.

Green flagellates and green coccoids predominated the phytoplankton in the adjacent Bay area, ranging from 1,000 to 20,000 per


88° 00'
87° 45'
45° 00'
45° 00'
44°45'
44°45'
87° 45'
LEGEND
Nos. of Organisms/Sq. Meter
0-500
500-2000
2000-5000
5000-15,000
Pollution-Tolerant
Pollution- Sensitive
Oconto R.
Oconto
Pensaukee R.
GREEN
BAY
N
0 1 2 3 4
scale in miles
Duck Cr.
Green Bay
Fox R.

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

BENTHIC FAUNA POPULATIONS
GREEN BAY NEAR THE OCONTO
AND FOX RIVERS, 1962-1963

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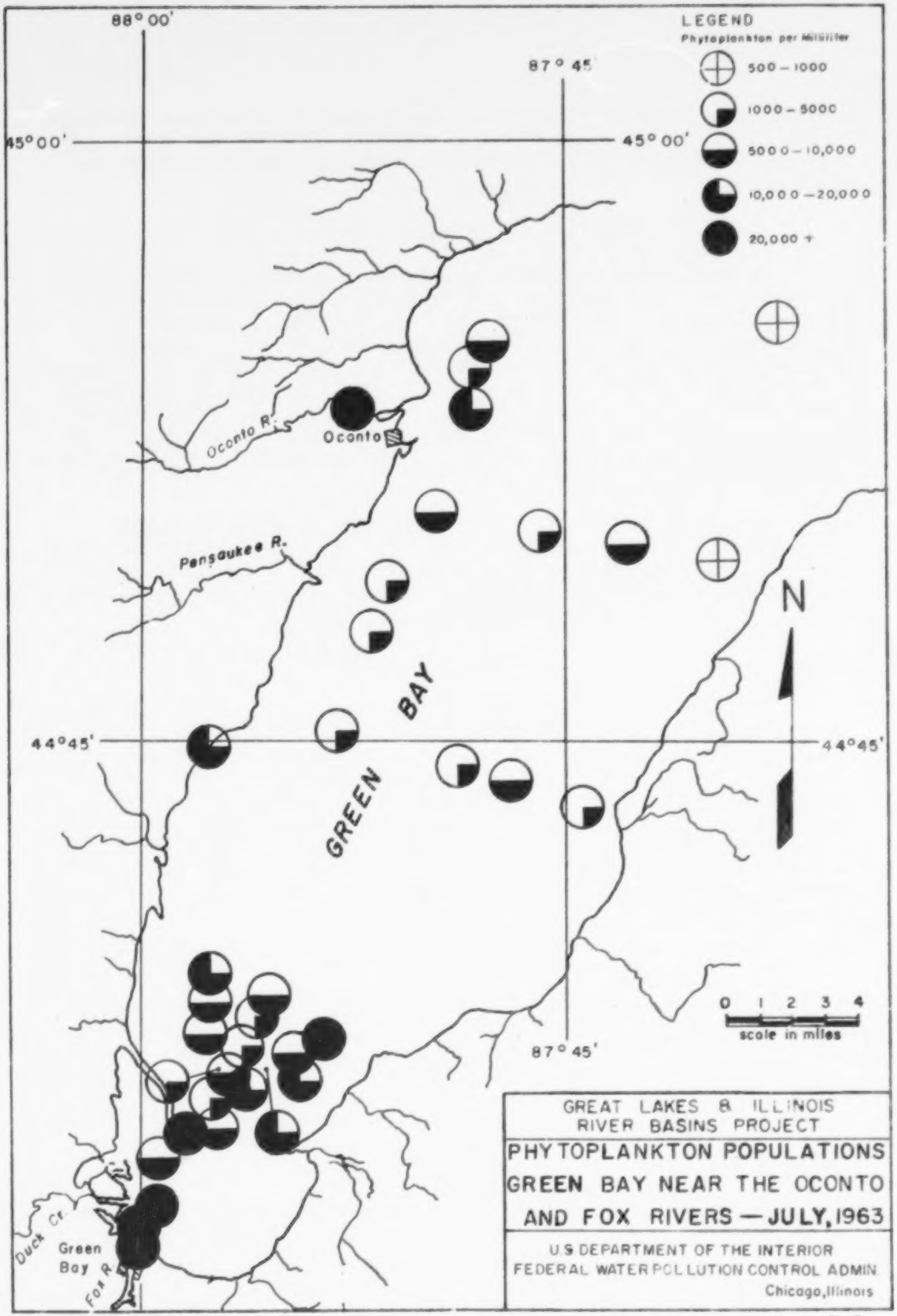
Chicago, Illinois

FIGURE 6-5


88° 00'
87° 45'
45° 00'
45° 00'
LEGEND
Phytoplankton per Milliliter
500 – 1000
1000 – 5000
5000 – 10,000
10,000 – 20,000
20,000 +
Oconto R.
Oconto
Pensaukee R.
GREEN BAY
N
44° 45'
44° 45'
0 1 2 3 4
scale in miles
87° 45'
Duck Cr.
Green Bay
Fox R.

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

PHYTOPLANKTON POPULATIONS GREEN BAY NEAR THE OCONTO AND FOX RIVERS — JULY, 1963

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FIGURE 6-6

milliliter as shown in Figure 6-6. The proportion of diatoms was higher in the Bay than in the Oconto River. Numbers of algae were considerably less on the eastern shore of Green Bay, ranging from 500 to 5,000 per milliliter.

Green Bay - Menominee and Peshtigo Rivers Tributary Areas

In 1962 and 1963 there were fewer bottom animals in the vicinity of the mouths of the Menominee and Peshtigo Rivers than there were in southern Green Bay. See Figure 6-7. A population of 800 per square meter, which consisted mainly of pollution-tolerant bloodworms and sludgeworms, was found near the mouth of the Peshtigo River. Twenty-five hundred organisms per square meter, mostly sludgeworms and bloodworms, were found at the mouth of the Menominee River. Rapid improvement in conditions and a predominantly sandy bottom were shown by the 1,300 scuds per square meter found in Green Bay about three miles from the mouth of the Menominee River.

As shown in Figure 6-8, similar numbers of plankton algae, ranging from 1,000 to 5,000 per milliliter, were found in the Menominee and Peshtigo Rivers and the adjacent waters of Green Bay in July 1963. The kinds of algae in these regions were green flagellates and centric diatoms, typical of enriched waters.

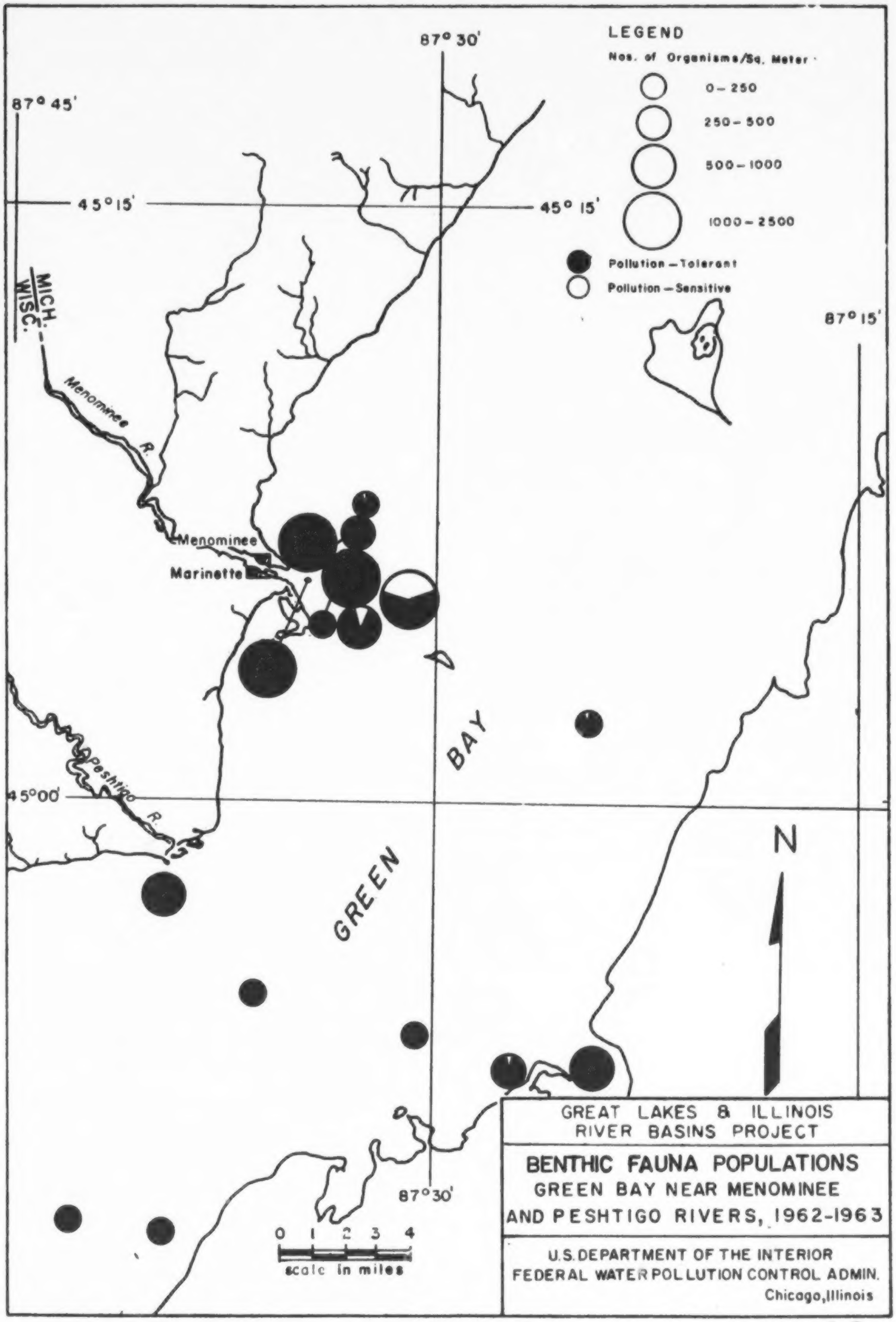
Adjacent Lake Michigan

In constrast to the waters in Green Bay, the northern part of Lake Michigan exhibited good water quality. This portion of the Lake was devoid of large numbers of sludgeworms. Generally, densities were less than 500 per square meter. Clean-water associated scuds were found in concentrations up to 2,000 per square meter. Bottom animal populations increased in Lake Michigan at the outlet of Sturgeon Bay, a possible result of enrichment by Green Bay waters. Light penetration of over 16 meters as measured with a secchi disc occurred in the northern waters of the Lake. In contrast, the lowest value, 0.2 meters, was found in Green Bay Harbor.

Green Bay Tributaries

Fox River. Biological investigations of the Fox River were conducted during October 1962 and May 1963. Six sampling stations were established from De Pere to the mouth of the River at intervals varying from one-half to two miles. There was an absence of bottom animals at each station during the first survey, indicating that the Lower Fox River was extremely polluted. Papermill woodwastes and ooze constituted the major portion of the bottom materials observed from De Pere downstream to Green Bay.

In May 1963, low numbers of bottom animals, 220 to 830 per square meter, occurred at each station. Pollution-tolerant sludgeworms and


LEGEND
Nos. of Organisms/Sq. Meter
0 – 250
250 – 500
500 – 1000
1000 – 2500
Pollution – Tolerant
Pollution – Sensitive
87° 30'
87° 45'
45° 15'
45° 15'
87° 15'
45°00'
87°30'
MICH.
WISC.
Menominee R.
Menominee
Marinette
Peshtigo R.
GREEN
BAY
N
0 1 2 3 4
scale in miles

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

BENTHIC FAUNA POPULATIONS
GREEN BAY NEAR MENOMINEE
AND PESHTIGO RIVERS, 1962-1963

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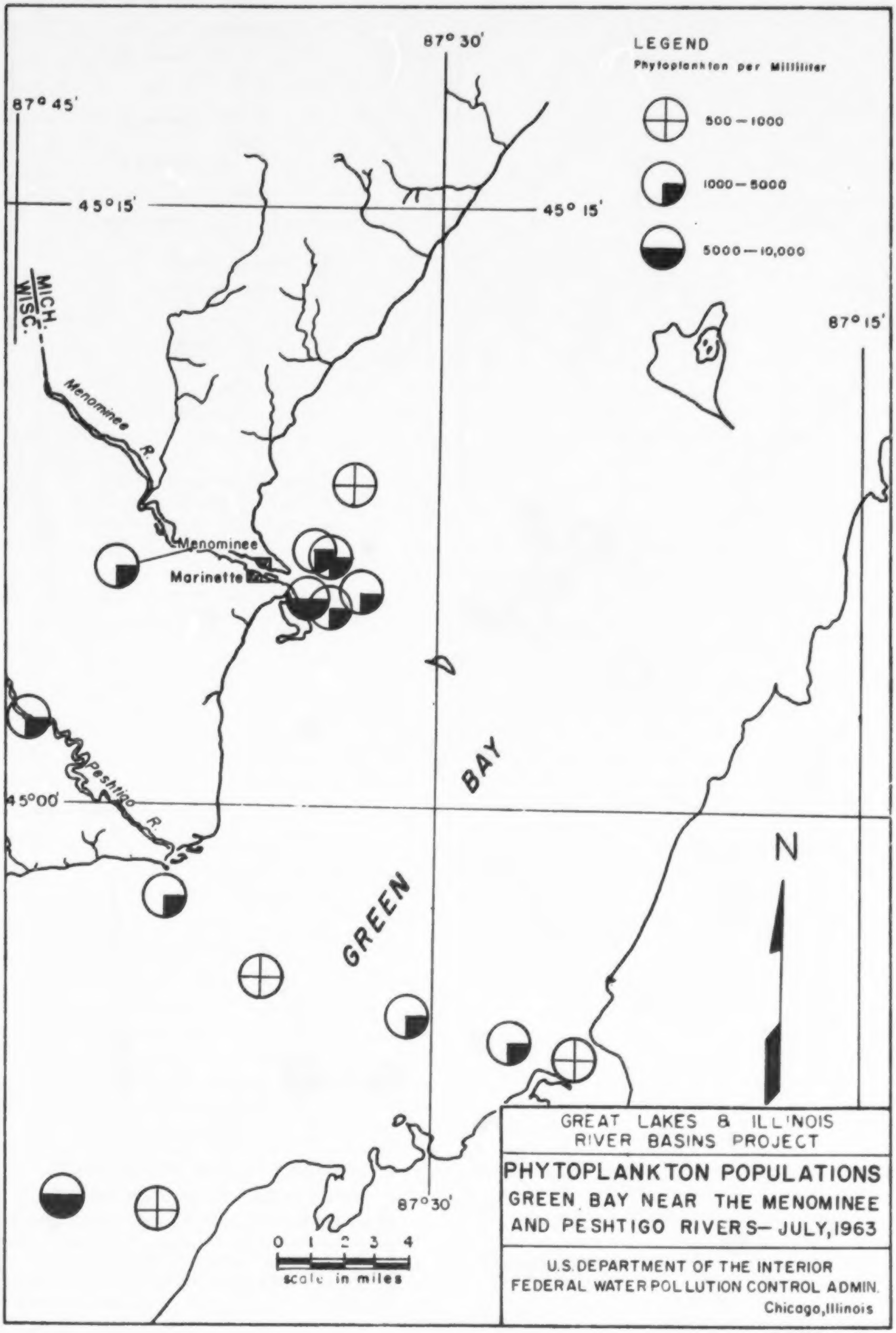
FIGURE 6–7


87° 30'
87° 45'
LEGEND
Phytoplankton per Milliliter
500—1000
1000—5000
5000—10,000
45° 15'
45° 15'
MICH.
WISC.
Menominee R.
Menominee
Marinette
87° 15'
Peshtigo R.
45°00'
BAY
GREEN
N
87° 30'
0 1 2 3 4
scale in miles

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

PHYTOPLANKTON POPULATIONS
GREEN BAY NEAR THE MENOMINEE
AND PESHTIGO RIVERS— JULY, 1963

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Chicago, Illinois

FIGURE 6-8

bloodworms were predominant among the bottom fauna. Only a few pollution-sensitive forms, 10 per square meter, were found at DePere and two miles downstream.

Phytoplankton populations were predominantly composed of green and blue-green coccoid forms, typical of organically enriched streams. Peak populations of 28,300 phytoplanktons per milliliter occurred during a sampling survey in August 1964.

Oconto River. The Oconto River, between the City of Oconto and the River's mouth, was sampled for bottom animals during May 1963 and for phytoplankton from June 1963 to March 1964. The section of the River studied was found to be severely polluted. Populations of pollution-tolerant sludgeworms and bloodworms, the only fauna found, ranged from 400 to over 2,500 per square meter.

Floating masses of pollution-tolerant filamentous blue-green algae were observed at all stations. Phytoplankton counts were high, with an observed midsummer peak count of 75,000 per milliliter. Green coccoids, flagellates and blue-green filamentous forms, typical of organically enriched streams, predominated.

Below the Oconto sewage treatment plant the bottom type changed from sand to decaying organic matter and sand. This provided a more suitable substrate for sludgeworm growth indicated by the increase in the sludgeworm populations near the mouth of the River.

Peshtigo River. The Peshtigo River was sampled for benthic organisms in May 1963 and for phytoplankton from June 1963 until March 1964. Good water quality conditions were found above the Badger Paper Mills in Peshtigo. Bottom samples contained many organisms associated with clean waters, such as scuds and mayfly larvae. The phytoplankton population also reflected good water quality at this station. Counts were low -- 2,400 organisms per milliliter was the summer peak. There was also a wide diversity of genera, mainly within the pennate and centric diatom groupings.

A drastic deterioration in water quality occurred, however, in the few remaining miles of the stream to its mouth. The bottom organism population consisted mostly of large numbers of sludgeworms and bloodworms, over 2,000 per square meter. All other pollution-tolerant forms were absent. Sphaerotilus or sewage fungus growths were observed. The dominant bottom type was ooze. The degraded conditions were apparently the combined result of waste discharge from the Peshtigo sewage treatment plant and the Badger Paper Mills.

Menominee River. Bottom dwelling animals were sampled during October 1962 and May 1963. Phytoplankton samples were collected from April to October 1963. Four stations were established at approximate three-quarter mile intervals upstream from the River mouth.

The quality of the Menominee River as it entered Green Bay was degraded. Only pollution-tolerant benthic organisms were found and over 800 sludgeworms per square meter were collected near the mouth. The total lack of organisms at some stations and reduction in numbers at others in October indicated that degraded conditions through the summer practically eliminate the small bottom-dwelling community. The River above the sewage treatment plants of Menominee and Marinette seemed to be in slightly better condition. More kinds of organisms, even though few in number, were found there.

A peak of 10,700 phytoplankton per milliliter was noted in April 1963. The dominant phytoplankton which were present, centric diatoms and green flagellates, are usually considered relatively insensitive to pollution. Heavy growths of fungus were found at all stations and indicated poor water quality.

Ford River. Biological sampling of the Ford River consisted of a phytoplankton survey. Samples were collected from June 1963 to March 1964 in the Ford River, Michigan. The phytoplankton data indicated excellent water quality. Total counts were very low throughout the year. Twenty-one hundred organisms per milliliter was the September maximum. Pennate diatoms, which are clean-water associated, predominated the population.

Escanaba River. Bottom Samples were collected from the Escanaba River during May 1963 and indicated degraded conditions. The mouth of the River was devoid of bottom animals. Upstream 1.7 miles, large numbers of pollution-tolerant bloodworms, over 2,900 per square meter, were collected. Only a few pollution-sensitive forms were found. Pulp and paper mill wastes predominated the bottom materials two miles upstream. Three miles upstream the River bed was flat, hard rock covered with slime and fungus.

Whitefish River. The Whitefish River, sampled near the mouth for bottom animals during may 1963, was moderately degraded. The bottom materials were predominately sand. The fauna was composed of pollution-tolerant clams and bloodworms, over 1,700 per square meter.

Microbiological Aspects

General

The kinds and numbers of bacteria found in a given volume of water provide valuable information with respect to the sources of contamination likely to render the waters unfit or of impaired quality for certain uses, particularly water supply, and recreation. Coliforms, fecal coliforms and fecal streptococci indicate the likely presence of wastes of human or animal fecal origin, with the danger of associated pathogenic organisms such as typhoid, paratyphoid and salmonellae, and enteric parasites. The higher the numbers, the greater chance that enteric pathogens are present, with the correspondingly greater threat to the health of those exposed to or consuming such waters. To assess the sanitary quality of the waters of the Green Bay Area, the GLIRB Project conducted microbiological testing during the 1962 to 1964 studies.

Green Bay and Tributary Mouths

In general, throughout the open Bay waters, the coliform densities were less in the northern parts than in the south Bay areas. The higher coliform densities occurred near urban centers and at the confluence of the tributaries as shown in Figure 6-9. The highest total coliform counts were encountered near the Menominee, Escanaba and Sturgeon Rivers and were in the range of 110 - 1,000 per 100 ml. At the east end of the Sturgeon Bay inlet the same range existed.

Fecal streptococci values, obtained from a survey study in 1962 indicate a range from 1 - 130 per ml. near the Menominee River mouth. Ranges at the Escanaba River mouth and in the Sturgeon Bay area were 1 - 24 and 1 - 16 per ml. respectively.

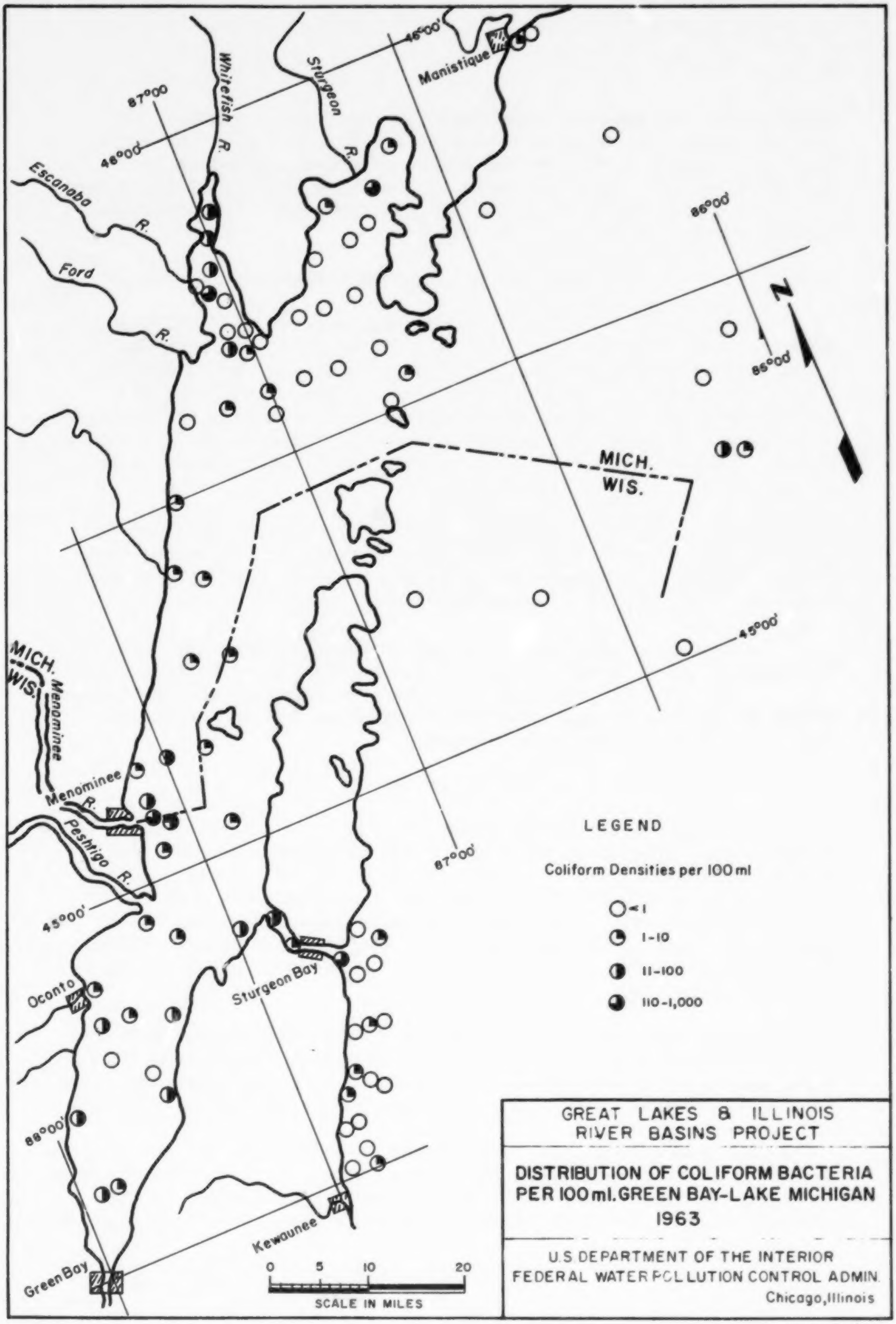
A summary of the bacterial densities found near the mouths of the tributaries is shown in Table 6-4. Few samples were collected near the mouth of the Fox River in Green Bay, because of the shallow depths prevailing at that time which prevented the collecting of samples outside of the dredged channel.

Fox River Survey

In August and November 1964, the Fox River, between Lake Winnebago and Green Bay, was sampled for total coliform and fecal streptococci densities. The results are shown in Figures 6-10 and 6-11. Total coliform densities ranged from less than 1,000 to 600,000 per 100 ml. In general, the densities observed in August were higher than those observed during the November study. Highest densities were found from Little Rapids upstream to the Kimberly, Wisconsin area.

Fecal streptococci findings follow the same general patterns as the coliform results. Streptococci densities ranged from five to 7,000 per ml. Highest densities were found in both August and November between little Rapids and Kimberlay, Wisconsin.

One noteworthy observation found in comparisons of the coliform and fecal streptococci densities is that total coliforms were highest in August, whereas fecal streptococci counts were highest in the November study. This may further substantiate what has been observed


46°00'
87°00'
46°00'
Manistique
Whitefish R.
Sturgeon R.
Escanaba R.
Ford R.
86°00'
86°00'
N
MICH.
WIS.
MICH.
WIS.
Menominee
Menominee R.
Peshtigo R.
45°00'
45°00'
87°00'
Oconto
Sturgeon Bay
88°00'
Kewaunee
Green Bay
0 5 10 20
SCALE IN MILES
LEGEND
Coliform Densities per 100 ml
○ <1
◔ 1-10
◑ 11-100
◕ 110-1,000

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

DISTRIBUTION OF COLIFORM BACTERIA PER 100 ml. GREEN BAY-LAKE MICHIGAN 1963

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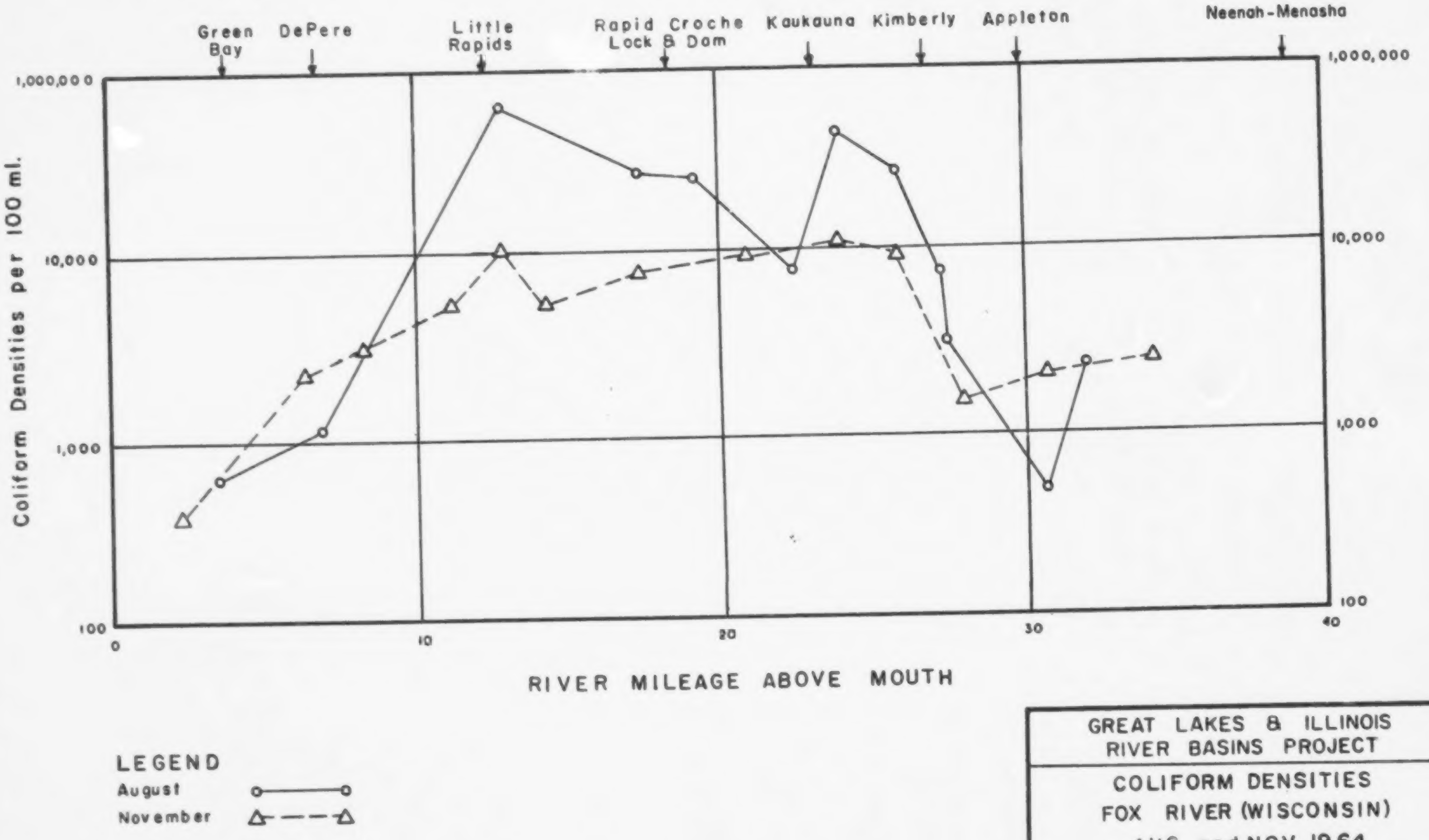
FIGURE 6-9

TABLE 6-4

DETERMINATIONS OF BACTERIAL DENSITIES
IN
GREEN BAY NEAR TRIBUTARY MOUTHS
1962-1963

Location	Total Coliform (per 100 ml.) No. Samples	Total Coliform (per 100 ml.) Range	Total Coliform (per 100 ml.) Geo. Mean	Fecal Streptococci (per ml.) No. Samples	Fecal Streptococci (per ml.) Range	Fecal Streptococci (per ml.) Geo. Mean
Menominee River @ Green Bay	22	< 1-350	8	11	1-130	4
Escanaba River @ Green Bay	16	20-350	94	11	< 1-24	3
Sturgeon Bay Area	13	< 1-250	4	3	< 1-16	3
Fox River @ Green Bay	7	2-22	6			
Oconto River @ Green Bay	6	< 1-11	4			

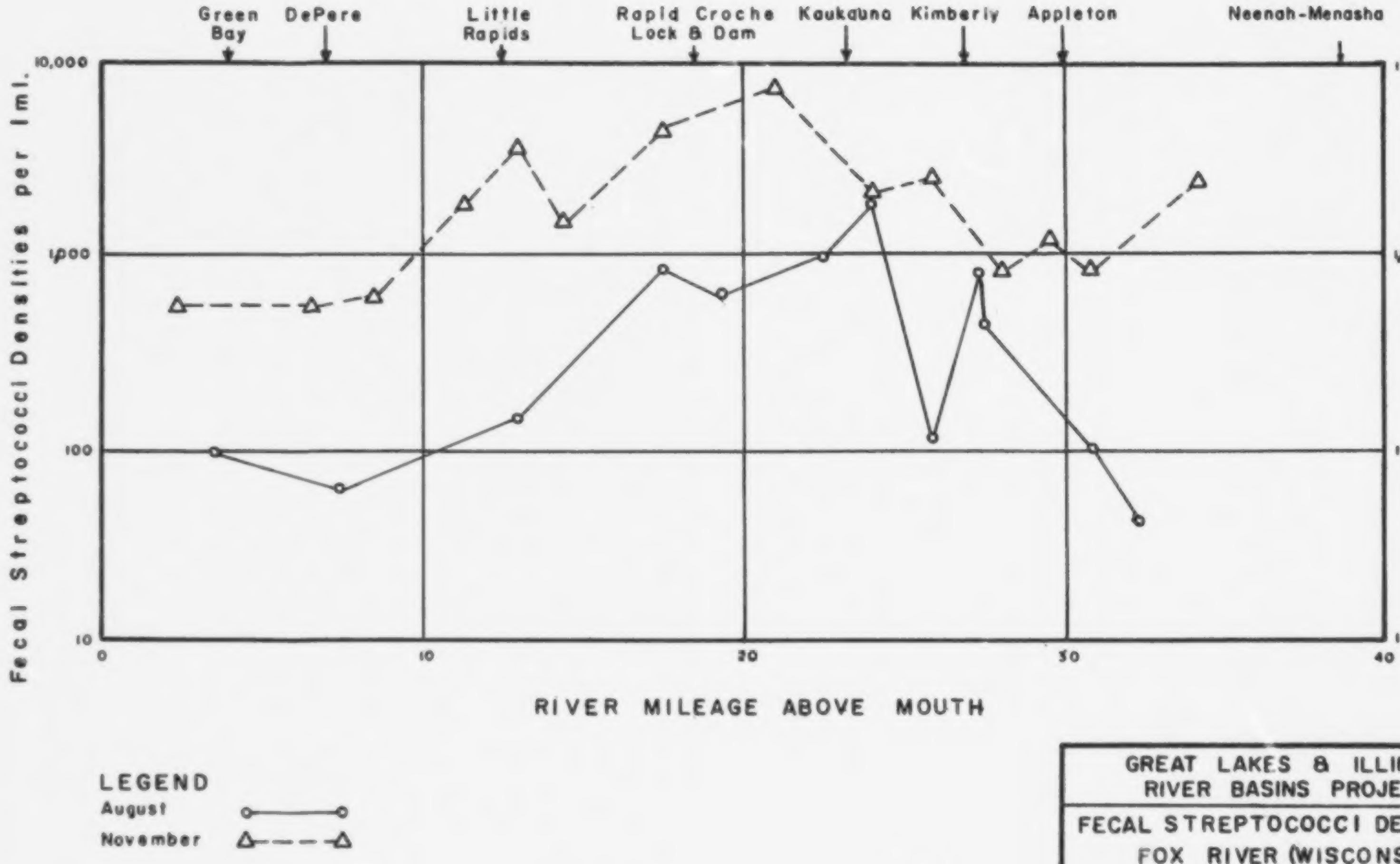


GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

COLIFORM DENSITIES
FOX RIVER (WISCONSIN)
AUG. and NOV. 1964

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Chicago, Illinois

FIGURE 6-10



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

FECAL STREPTOCOCCI DENSITIES
FOX RIVER (WISCONSIN)
AUG. and NOV. 1964

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Chicago, Illinois

FIGURE 6-11
]

in other studies in different areas, that fecal streptococci tend to persist longer in the spring and fall seasons.

Evaluation of both coliform and fecal streptococci densities in this 34 miles of the Fox River indicates pollution of fecal origin. Consumers dependent upon these water resources are exposed to serious health hazards as well as increased water processing costs.

Waste Assimilation

Based on a consideration of the location of municipal and industrial waste discharges in the Green Bay Area and the characteristics of the waters receiving these wastes, four reaches of streams were selected for waste assimilation studies. These were the Lower Fox River, Menominee River below Niagara and certain reaches of the Oconto and Peshtigo Rivers.

Lower Fox River

Waste assimilation stream studies were conducted by the GLIRB Project to determine the total streamflow required to meet a range of water quality goals in the Lower Fox River. The 34 mile stretch of the Lower Fox River from Appleton to Green Bay is the most critical reach within the River. In 1964, intensive stream investigations were conducted on this reach during June, August and November.

A computer program was utilized to develop a mathematical model which reproduced the stream conditions observed during these intensive sampling periods. Using projected flow and quality data for the waste inputs within the study reach of the stream, the model was used to compute the total streamflows required for flow regulation for water quality control. It has been assumed that a 90% 5-day BOD (BOD_5) removal will be provided by 1980 and a 95% BOD_5 removal will be provided by 2020 for both municipal and industrial waste discharges.

Based on the desired uses of the Lower Fox River as given in Table 3-1 and a consideration of the water quality criteria necessary to support these uses, a minimum dissolved oxygen concentration of 3.0 mg/l was the minimum water quality goal in this reach of stream. The maintenance of this minimum goal will assure the absence of nuisance odor conditions; permit recreational use involving body contact (when municipal waste treatment plants provide effluent disinfection); support some fish and other aquatic life; and in general provide for the esthetic enjoyment of unpolluted surface waters.

The ranges of total streamflow required to maintain a minimum DO concentration of 3 mg/l are 290 to 2700 cfs in 1980 and 200 to 3800 cfs in 2020. It should be remembered that these are only estimates of the required streamflow and are no better than the weakest assumption made in developing the stream model.

The ability of existing streamflow to meet the above demand is assessed by comparing the maximum required flows in 1980 and 2020 with the 7 day once-in-10-year low flow given in Table 2-2. Thus it can be concluded that streamflow regulation or increased treatment, beyond 95% BOD removal, may be required if the water quality goal of 3 mg/l DO is to be maintained.

Other Critical Reaches

The projected future untreated waste load of the areas selected as being most critical were determined. The degree of treatment efficiency appropriate to the date of the projection was employed to determine the waste load to the stream. A stream flow approximating the once-in-10-year 7 day low flow at the point of waste input was selected as being critical as far as water quality control was concerned. Based on consideration of the stream uses and water quality criteria as given in Tables 3-1 and 3-7, the water quality parameter of concern was the dissolved oxygen (DO) content of the stream. Computations summarized in Table 6-7 show the flow regulation will not be necessary for water quality control below Niagara on the Menominee River, Oconto Falls on the Oconto River and Peshtigo on the Peshtigo River provided that adequate waste treatment is utilized.

TABLE 6-5

ESTIMATED DISSOLVED OXYGEN CONCENTRATIONS FOR CRITICAL STREAM SECTORS IN THE GREEN BAY AREA

Approximate Location	Projected 1980 Waste Load to Stream (1)		River, mileage and 1 in 10 year 7 day low flow at location stated in cfs.	Estimated in Stream total ultimate (2) Oxygen Demand (mg/1)	(3) k_1 k_2	Calculated Critical Concentration mg/1 (4)	Criteria(5) Minimun DO mg/1
	#BOD/DAY	MGD					
Oconto Falls	5000	14.9	Oconto River, 179 (mile 22.9)	27.2	0.62 3.22	5.1	4.0
Niagara	7200	13.5	Menominee River, 540 (mile 85.1)	21.0	0.46 2.3	5.9	4.0
Peshtigo	8000	7.3	Peshtigo River, 210 (mile 10.4)	36.8	0.46 2.3	4.0	4.0

(1) Based on the projected raw waste load receiving an estimated degree of treatment of 90% in terms of BOD_5 reduction.
(2) Based on GLIRBP data the calculated in stream BOD_5 X 4.5 = total ultimate demand as an estimate.
(3) From GLIRBP data.
(4) Streeter-Phelps OX-SAG equation used here, assuming initial DO deficit as 0.2 X saturation value of 20°C.
(5) See Table 3-1 and 3-7.

CHAPTER 7

QUALITY IMPROVEMENT MEASURES

General

The problems of water pollution control in the Green Bay Area are complex. Solutions to these problems will of necessity involve a comprehensive program which includes construction of new sewerage facilities; and continuous and intensive monitoring of operating procedures, treatment plant efficiency, and water quality conditions to determine necessary additional construction and operation needs as they arise. In addition, flow regulation may be required to attain the desired water quality in the Lower Fox River even after a high degree of waste treatment is accomplished. These phases of the comprehensive program for pollution control in the Green Bay Area are discussed in the following paragraphs.

Municipal Waste Treatment

The immediate goal in the treatment of municipal wastes is the provision of biological (secondary) treatment at each waste treatment plant. Such treatment is considered adequate in terms of present technology and provides 90 percent BOD_5 removal. Adequate effluent disinfection is also considered to be a necessity in the study area particularly where recreational use of the receiving waters is prevalent. There is also a present need for increased phosphate removal.

There are approximately 75 municipal sewerage facilities in the Green Bay Area. Of these 52 provide secondary biological waste treatment.(14) Municipal waste treatment construction needs for the major communities of the Green Bay Area are shown on Table 7-1. These needs are based on waste flow and waste load projections to the year 1980.

It is estimated that the total cost of needed municipal plant improvements shown in Table 7-1 but excluding facilities specifically for phosphate removal, is $7,900,000. Of this amount some $5,400,000 will be required for municipal waste treatment needs along the Lower Fox River. The average annual cost per person for the immediate municipal waste treatment construction needs and for the perpetuation of these new facilities and existing municipal waste treatment facilities is estimated to be $3.20. This is based on the present sewered population.

TABLE 7-1

MUNICIPAL WASTE TREATMENT CONSTRUCTION NEEDS (MAJOR COMMUNITIES)
GREEN BAY AREA - MICHIGAN AND WISCONSIN

Community	Present Status	Population Connected	Needs
	Green Bay Perimeter		
Marinette, Wisconsin	Pri. Tr.	13,000	Sec. Tr.
Menominee, Michigan	Pri. Tr.	11,280	Sec. Tr.
Escanaba, Michigan	Sec. Tr.	15,390	None
Gladstone, Michigan	Pri. Tr.	5,260	Sec. Tr.
	Lower Fox River		
Green Bay, Wisconsin	Sec. Tr.	88,280	Enlargement
DePere, Wisconsin	Sec. Tr.	10,100	Enlargement
Appleton, Wisconsin	Sec. Tr.	47,000	Enlargement
Little Chute, Wisconsin	Sec. Tr.	5,100	Enlargement Disinfection
Kimberly, Wisconsin	Sec. Tr.	5,400	Enlargement Disinfection
Kaukauna, Wisconsin	Sec. Tr.	10,100	Enlargement
Neenah & Menasha, Wisconsin	Pri. Tr.	32,705	Sec. Tr.
	Upper Fox and Wolf Rivers		
Fond du Lac, Wisconsin	Sec. Tr.	33,000	None
Oshkosh, Wisconsin	Sec. Tr.	50,685	Enlargement
Ripon, Wisconsin	Sec. Tr.	6,765	Disinfection

TABLE 7-1 (Continued)

MUNICIPAL WASTE TREATMENT CONSTRUCTION NEEDS (MAJOR COMMUNITIES) GREEN BAY AREA - MICHIGAN AND WISCONSIN

Community	Present Status	Population Connected	Needs
Berlin, Wisconsin	Sec. Tr.	4,830	None
Portage, Wisconsin	Sec. Tr.	7,800	Enlargement Disinfection
Waupaca, Wisconsin	Pri. Tr.	4,000	Sec. Tr.
New London, Wisconsin	Sec. Tr.	5,300	Enlargement Disinfection
Clintonville, Wisconsin	Sec. Tr.	4,800	Enlargement Disinfection
Shawano, Wisconsin	Sec. Tr.	6,300	None
	Oconto River		
Oconto Falls, Wisconsin	Sec. Tr.	2,300	Disinfection
Oconto, Wisconsin	Sec. Tr.	4,700	None
	Peshtigo River		
Peshtigo, Wisconsin	Sec. Tr.	2,800	None
	Menominee River		
Iron Mountain - Kingsford, Michigan	Pri. Tr.	14,370	Sec. Tr.
Niagara, Wisconsin	Pri. Tr.	22,000	Sec. Tr.

Industrial Waste

As described in Chapter 4 pulp and paper mill waste are the largest source of pollution in the Green Bay Area. Re-examination of Table 4-2 will show that in general industries of the Area provide only limited waste treatment facilities. Many of the plants only screen waste while others provide some lagooning, settling or evaporation of the sulfite liquor. While research has been conducted for some time to determine new and more profitable ways to use the waste products of the paper industry, gross pollution of public and interstate waters continues.

Minimum industrial treatment needs are listed in Table 7-2. In developing this list it was considered that the equivalent of secondary waste treatment as described in the preceding section would be required. In some areas such as the Lower Fox River, additional treatment (beyond 90% BOD_5 removal) and/or flow regulation may be required if the desired water quality goals are to be met. The recommended BOD_5 load limits shown on Table 7-2 were arrived at by estimating the present raw load and projecting this figure to 1980 by using an industrial growth multiplier. Then a 90% BOD_5 removal of the 1980 raw load was applied. The present raw load used in the above calculation was estimated from a knowledge of the existing discharged waste load and existing treatment practices.

In addition to necessary reduction in the organic waste load from industry certain other measures are necessary. These include reduction of suspended solids and secondary biological treatment and disinfection of plant sanitary wastes.

Combined Sewers

Historically, the development of our Nation's sewer system followed a general pattern. Diversion of storm water was the earliest concern of communities. Discharges were made directly to watercourses, usually at many points. Later these sewer systems were used to carry sanitary sewage also. As the public became increasingly aware of the need for treatment of sanitary wastewater, the many short sewers discharging untreated domestic waste to various points in streams were provided with interceptors and the collection system modified to deliver the waste to a single point - the treatment plant. When sanitary and storm water are combined it is necessary in times of high flow to have the sewers overflow directly to the stream.

Studies of combined sewer systems have indicated that the combined overflow contain from 3 to 5 percent of the average annual untreated domestic sewage. During storms as much as 95 percent of the sewage flow is discharged with the storm water runoff. Storm water

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TABLE 7-2

PLANT WASTE REDUCTION NEEDS FOR MAJOR INDUSTRIAL WASTE SOURCES

GREEN BAY AREA

		Waste Discharge Stream Loading Rate (lbs. 5-day BOD/DAY)		
		Present	Recommended Limit	
		Lower Fox Area		
Company	Location			Comment Secondary Treatment or Equivalent (90% BOD_5 Removal)
Green Bay Packaging	Green Bay	33,300	6,150	"
Charmin Paper Co.	Green Bay	45,920	10,200	"
Marathon Paper Co.	Green Bay	46,920	16,900	"
Fort Howard Paper Co.	Green Bay	28,440	9,400	"
U.S.Paper Mills Corps.	De Pere	-	-	"
Nicolet Paper Co.	De Pere	200	40	"
Charmin-Little Rapids	Little Rapids	228	40	"
Thilmany Paper Co.	Kaukauna	33,080	11,100	"
Combined Locks Paper Co.	Combined Locks	4,200	890	"
Kimberly Clark Co.	Kimberly	52,740	15,500	"
Consolidated Paper Co.	Appleton	33,620	7,500	"
Riverside Paper Co.	Appleton	1,940	360	"
Fox River Paper Co.	Appleton	-	-	"
Whiting Paper Co.	Menasha	128	25	"
Marathon Paper Co.	Menasha	-	-	"
John Strange Paper Co.	Menasha	1,680	310	"
Gilbert Paper Co.	Menasha	1,040	190	"
Kimberly Clark Co.	Neenah	2,400	450	"
Bergstrom Paper Co.	Neenah	3,680	890	"
Kimberly Clark Co. (Badger-Globe)	Neenah	340	60	"
Kimberly Clark Co. (Neenah Div.)	Neenah	588	110	"

TABLE 7-2 (Cont'd.)

PLANT WASTE REDUCTION NEEDS FOR MAJOR INDUSTRIAL WASTE SOURCES

GREEN BAY AREA

		Waste Discharge Stream Loading Rate (lbs. 5-day BOD/day)		
		Present	Recommended Limit	
		Oconto-Peshtigo River		
Company	Location			Comment Secondary Treatment or Equivalent (90% BOD_5 Removal)
Scott Paper Co.	Oconto Falls, Wisconsin	38,000	4,900	"
Badger Paper Mills	Peshtigo, Wisconsin	22,900	11,700	"
		Menominee River		
Scott Paper Co.	Marinette, Wisconsin	52,900	10,000	"
Scott Paper Co.	Menominee, Michigan	910	120	"
Marathon Paper Co.	Menominee, Michigan	4,410	660	"
Kimberly Clark	Niagara, Wisconsin	17,360	7,200	"
		Escanaba River		
Mead Corp.	Escanaba, Michigan	11,150	2,300	"

alone was demonstrated to carry significant amounts of pollution load, particularly in the early portions of storms when a flushing action occurs in the sewers. The storm water washes large amounts of deposited sludge out of the sewers. For example, data from Buffalo, New York some years ago indicated that one-third of the City's annual production of sewage solids overflowed without treatment, although only 2 to 3 percent of the sewage volume actually overflowed.(16)

The need for solutions to the problems caused by overflows from combined sewer systems is pressing and is receiving much current attention.(23) The Water Quality Act of 1965 established a four-year program of grants and contract authority to demonstrate new or improved methods to eradicate the problems of combined sewer overflows.

Until economically feasible methods for solving the problems are developed, existing combined sewer systems should be patrolled. Overflow regulating structures should be adjusted to convey the maximum practicable amount of combined flows to and through waste treatment facilities. Combined sewers should be prohibited in all newly developed urban areas and in coordination with urban renewal projects.

Reduction of Nutrients

There is an immediate need for the reduction of the nutrient loads to Green Bay. Concentrations of phosphate in nearly every zone in Green Bay were far above the level of 0.03 mg/l considered critical for the stimulation of algal blooms. That portion of Green Bay at the mouth of the Fox River had a phosphate (PO_4) concentration of 0.20 mg/l many times the 0.03 critical level. At present Green Bay receives some 5 million pounds of phosphate annually from its watershed. The largest single tributary source is the Fox River which discharges 2,400,000 pounds annually.

The degree of phosphate removal attained by the municipal and industrial treatment plants in the Green Bay Area is not known. However, the removal of phosphates is known to vary among plants of similar design for reasons that are not always evident. Research in progress shows promise of accomplishing substantial removals at nominal cost. It may be necessary in the future to use some form of advanced waste treatment to further remove phosphates.

Plant Operation

It is not enough for a community to build a secondary biological waste treatment plant; the plant must also be operated efficiently. Of the 52 communities in the Green Bay Area with secondary treatment plants, several are operating at less than 85% efficiency in the removal of BOD_5. A review of the available inventory data relating to the design capacities and removal efficiency of treatment plants in the area indicates that the following plants which presently provide secondary treatment, need operational improvements:

Green Bay, Wisconsin
Wrightstown, Wisconsin
Oshkosh, Wisconsin
Birnamwood, Wisconsin
Markeson, Wisconsin
Wautonia, Wisconsin
New London, Wisconsin
Manana, Wisconsin
Peshtigo, Wisconsin
Escanaba, Michigan
Little Chute, Wisconsin
Fond du Lac, Wisconsin
Berlin, Wisconsin
Bonduel, Wisconsin
Montello, Wisconsin
Hortonville, Wisconsin
Iola, Wisconsin
Shawano, Wisconsin
Crandon, Wisconsin

Overloading of the following existing secondary facilities has contributed to low treatment efficiencies:

De Pere, Wisconsin
Appleton, Wisconsin
Pardeeville, Wisconsin
Lena, Wisconsin
Stephenson, Michigan
Kaukauna, Wisconsin
North Fond du Lac, Wisconsin
Clintonville, Wisconsin
Coleman, Wisconsin

Proper plant operation must follow proper plant design in order to efficiently reach the goals of water pollution control. The importance and value of proper plant operation must be emphasized at all levels of public authority. Effective operation can be encouraged by means of a routine inspection program. Inspections should be conducted by the appropriate State agencies on at least an annual basis for the small and medium-sized plants, and at least, bi-annually for the larger plants.

The Wisconsin Sewage Works Operators Association administers a voluntary sewage treatment plant operators' certification program in Wisconsin. A mandatory certification plan is under consideration. The voluntary program is commendable and can provide definite incentive for the proper operation of waste treatment plants. However, a mandatory program is preferrable to insure the proper qualifications of operators. Michigan already has a mandatory program.

State-sponsored operator training programs are also a useful tool for elevating the level of overall plant performance. The existing training program in Wisconsin is a step in the right direction and consists of a 3-day biennial course sponsored by the State Board of

Health, University of Wisconsin, and the League of Wisconsin Municipalities. However, the Wisconsin program does not compare favorably with the frequency and duration of such training sponsored by other states. Michigan for example sponsors annual training programs. Today, with increasing activity in the field of water pollution control at the Federal, State and local levels operator training courses should be conducted at least annually.

Monthly operation reports should be submitted to the States water pollution control agencies from each municipal and industrial waste treatment facility. These reports should contain sufficient information to describe waste treatment efficiency and the quality and quantity of the effluent discharged to the water of the Green Bay Area. Monthly operational reports would provide the State with more current information and would enable them to take much quicker action concerning needed improvements.

Monitoring

The maintenance of desirable water quality on a continuing basis calls for a routine monitoring program covering the significant water quality parameters at strategic points.

The monitoring program of the Wisconsin Committee on Water Pollution should be strengthened and coordinated with the other agencies at the Federal, State and local levels. The monitoring program of the Michigan Water Resources Commission should be expanded to include those streams in the Green Bay Area within the State of Michigan. The Federal Water Pollution Control Administration will cooperate and assist the Committee and Commission to the fullest extent of its resources and personnel in expanding its monitoring program.

The industries, municipalities and other agencies, discharging wastes within the study area, should submit monthly reports to the appropriate State agency concerning the quality and quantity of the wastes discharged. These reports could, in many cases, be combined with the monthly operational report which was discussed under "Treatment Plant Operation."

The overall monitoring program should be geared to provide an adequate picture of all wastes being discharged to the waters of the area and serve to indicate trends in water quality or the need for additional water quality improvement measures.

Flow Regulation

Water quality levels for various streamflows at 4 critical Green Bay tributary locations were determined as discussed in Chapter 6. In one instance, the Lower Fox River, it appears that streamflow regulation may be required to improve water quality even after a high degree of waste treatment efficiency is achieved. However, flow regulation will not be considered as a quality improvement measure until after a high degree of treatment is attained. Flow regulation will not be used as a substitute for treatment measures recommended in this report.

State Water Pollution Control Program

The Federal Water Pollution Control Act recognizes the primary responsibility of the States in the control and prevention of water pollution. The effectiveness of a State program, however, is dependent upon adequate funds and personnel with which to accomplish this mission.

The States of Michigan and Wisconsin have achieved commendable success in the control of water pollution with the staff and funds available. However, even though much has been accomplished by the States in controlling conditions, much remains yet to be done. In 1964, the Public Administration Service prepared a survey report for the Public Health Service concerning the budgeting and staffing of State programs.(29) This report, containing suggested guidelines for use in evaluating the adequacy of State water pollution control programs, may be of assistance to Michigan and Wisconsin in terms of evaluating their present water pollution control efforts.

In view of the water pollution control problems still existing in Michigan and Wisconsin, consideration should be given by the States to an accelerated program to match the needs of the States for clean water for all legitimate uses. An accelerated State water pollution control program utilizing fully the resources and programs of the Administration will ensure the earliest possible accomplishment of our common goal - more effective use of our water resources.

CHAPTER 8

PROGRAM IMPLEMENTATION

The implementation of the comprehensive water pollution control program for Lake Michigan Basin will involve the combined efforts of the water pollution control agencies at all levels of government. Specific recommendations for implementing the Lake Michigan Comprehensive Water Pollution Control Program, and for coordinating the subbasin programs will be contained in the Summary Report for Lake Michigan, which will be the final report in the Lake Michigan series. The recommendations contained in this report will in no way conflict with recommendations contained in the Green Bay Area water pollution control program, nor will it interfere in any way with any steps taken to implement those recommendations.

Accordingly it is recommended that the Comprehensive Water Pollution Control Program contained herein serve as the basis for improvement of the quality of the waters in the Green Bay Area. The Federal Water Pollution Control Administration will cooperate and assist to the fullest extent of its resources and personnel in each action taken to achieve objectives consistent with the Program.

CHAPTER 9

BENEFITS

Implementation of the recommendations which comprise the above action program will result in substantial improvement in the quality of the waters in the Green Bay Area. The program objectives, however, are more specific and have been developed to provide water of satisfactory quality for both present and planned uses as shown on Table 3-1. Accomplishment of program objectives will result in both tangible and intangible benefits to the people of the Green Bay Area in particular, and to the people of the States of Wisconsin, Michigan and the Nation as a whole. As the waters of Lake Michigan serve many States and are of National importance, all will share in the benefits resulting from the enhancement and protection of these waters for both present and future needs.

Residents of the study area will benefit from the assurance of a safer, more palatable water supplied to their homes, business establishments, industries, schools and public buildings. Owners of property adjacent to and near bodies of water will derive increased esthetic enjoyment and enhanced property values from the elimination of ugliness and unsightly conditions resulting from water pollution, including nuisance algal blooms stimulated by over-fertilization.

Michigan and Wisconsin residents and visitors from out-of-state who use the Area streams and lakes for swimming, water skiing, boating and other water-oriented sports will be protected against infectious diseases which can be spread as a result of water pollution. The sports fisherman will find additional fishing areas to challenge his skill and improved fishing as a benefit of enhanced water quality.

As a return on their investment in improved water quality, industry will share in the benefits through assurance of consistency in the quality of process water needed for many of its products and other water needs.

In addition to these immediate and direct benefits resulting from the control of pollution, the preservation and protection of the quality of the waters of Lake Michigan and the Great Lakes is an important benefit and essential to the Nation's continued growth and prosperity. This immense fresh water resource, the greatest in the world, is beginning to show the effects of man's carelessness. Lake

Erie is a clear demonstration that size is no protection against pollution and that man has the capability of destroying the usefulness of even a major water resource.

The Calumet, Milwaukee and Green Bay Areas of Lake Michigan are already affected adversely by pollution. Should the Lake as a whole reach critical levels of nutrients or other persistent contaminants, it would require many decades before remedial measures could result in restoration of satisfactory water quality.

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